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BULLETIN OF MARINE SCIENCE
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THE NEMERTEAN FAUNAS OF THE GULF OF MEXICO AND OF SOUTHERN FLORIDA

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ABSTRACT

Of the 22 species recorded, 16 were found on the northern Gulf coast and eight in southern Florida. Only two species were common to the two regions. With the exception of two species which appear to be endemic, all those of the northern Gulf coast represent boreal species which occur also on the east coast of North America, although the two faunas have been separated since Pleistocene times by the Florida peninsula. Those of southern Florida are tropical or subtropical forms and some of them are found also in the West Indies or northern South America. The ecological conditions of the northern Gulf coast are so different from those of southern Florida that a more or less complete separation of the littoral invertebrate faunas is not surprising.

The species are treated systematically with a brief description of each, keys for identification, and drawings of the characteristic features.

Nemerteans are found along all the sea-coasts of the world and off the shores to depths of hundreds of meters. Some of the species are circumpolar, extending southward along the Atlantic coasts as far as Madeira or South Africa on the east, and to southern New England or Florida or the Gulf of Mexico on the west, and in the Pacific to California or Mexico on the east and to Japan on the west. A few species live in both the northern and southern hemispheres and a few others in fresh-water streams and lakes. Some are limited to the polar seas and others to the tropics, but many have a wide geographical range and survive under a great variety of environmental conditions. Some of the bathypelagic species live at depths of 1000 to 2000 meters or more and the populations may be carried for thousands of miles by the deep ocean currents, reproducing generation after generation in their endless circuits throughout the great oceans. A few species are parasitic or commensal, while a few others are terrestrial and live beneath

[1]Contributions from the Scripps Institution of Oceanography, new ser., no. 538.

leaves and other objects in moist situations. More than 700 species have been described but only a few of them have been fully investigated.

Nemertean Faunas of the Gulf of Mexico

With the exception of the descriptions of new species, the only report on the nemerteans of the Gulf of Mexico is a brief summary of their geographical distribution published by Coe (1951). That report does not mention the diagnostic features by which the various species may be identified nor their habitat or other ecological peculiarities and these are therefore included in the present paper. The illustrations will aid in species identification. The following account is compiled from collections on the northern coast of the Gulf and from southern Florida. No information is yet available for all those portions of the Gulf coast between Franklin County and Key West, Florida, nor for all that portion of the western Gulf coast south of the Mexican border.

In the areas covered by this report only 16 species have been obtained from the northern Gulf coast and 8 from southern Florida. Only two of these have yet been found in both areas. The presumable explanation for this small number is that only sporadic efforts have been made toward a complete survey of the littoral fauna of those regions. On the Atlantic coast of North America there are 53 known species of nemerteans (Coe, 1943) and on the Pacific coast 95 species (Coe, 1940). Hence, it seems improbable that a very large proportion of all the species now actually living in the Gulf can be included in this report.

Even on the Atlantic coast the nemerteans have been studied extensively only as far south as New Jersey and our knowledge of the species living between that State and Florida is based on collections made at widely separated localities. It may therefore, be assumed that some, perhaps many, additional species remain to be discovered there.

Geographical distribution. All except two of the species at present known from the northern shores of the Gulf are also found on the Atlantic coast. Therefore, it may be assumed that the nemertean fauna of this part of the Gulf coast has in the geologically recent past been a continuation of that of the Atlantic coast. The present evidence indicates that it is now principally a separate fauna which has been

isolated since the last post glacial period in Pleistocene times by the Florida peninsula. To determine to what extent the species of the two areas are at present continuous or overlapping, it is essential to obtain additional collections on both sides of that peninsula. It is already known that some of the species found at Pensacola, on the Gulf side, are identical with those found at St. Augustine, on the Atlantic side. It is now evident that these two nemertean faunas are separated by an area in which other species predominate. Because of the great differences in the environmental conditions between the coasts of northern and southern Florida, a more or less complete separation, but with some overlapping, would seem probable. Only two of the eight species at present known from southern Florida have been found on the northern Gulf coast.

From the small amount of evidence at present available it would appear that the nemerteans on the northern Gulf coast and at St. Augustine, Florida, represent mainly boreal forms, while those at Biscayne Bay and Key West are mostly tropical or subtropical species. In other groups of invertebrates likewise, as well as in fishes, many of the boreal species extend southward along the North Atlantic coast as far as Cape Hatteras or northern Florida and are also found on the northern Gulf coast. The marine fauna of southern Florida, on the other hand, includes species which are identical with those of the West Indies and northern South America. The invertebrate fauna of the northern Gulf coast, however, may contain a mixture of boreal and subtropical species. Deevey (1950) found that the hydroids on the coasts of Louisiana and Texas were dominated numerically by tropical and subtropical forms but that a significant proportion of them were distinctly boreal in distribution.

None of the characteristic boreal and subarctic species of nemerteans of the Atlantic coast, such as *Amphiporus angulatus, A. lactifloreus, A. pulcher, Emplectonema giganteum, Lineus ruber,* or *Cerebratulus marginatus,* have been found in the Gulf. These species do not extend southward along the coast much farther than the Cape Cod region.

Since the coastal water on the west side of the Florida peninsula has a prevailingly northward movement, it is obvious that such of the subtropical species on the southern coast of the Florida peninsula as have free-swimming larvae will tend to be distributed in a corresponding

direction until they reach an area in which the conditions in winter are unfavorable for survival.

The nemerteans represent a conservative group and many of the species seem to thrive under a great variety of ecological conditions. As a consequence they often have a wide geographical distribution. Of the 16 species here recorded from the northern Gulf coast, all except *Paranemertes biocellata* and *Amphiporus texanus* are widely distributed on the Atlantic coast and four of them, namely, *Tubulanus pellucidus, Zygeupolia rubens, Zygonemertes virescens* and *Amphiporus cruentatus* occur also on the Pacific coast but not in Europe; two others, *Carcinonemertes carcinophila* and *Tetrastemma vermiculus* are found on European and American Atlantic coasts but not in the Pacific; *Oerstedia dorsalis, Tetrastemma candidum* and *Malacobdella grossa* are circumpolar, inhabiting European shores as well as both the Atlantic and Pacific coasts of North America, while the remaining five species, *Carinoma tremaphoros, Lineus socialis, Micrura leidyi, Cerebratulus lacteus* and *Amphiporus ochraceus* are known only from the Atlantic and Gulf coasts. *Paranemertes biocellata* and *Amphiporus texanus* have been found only on the northern Gulf coast and may possibly represent endemic species.

For comparison, it may be noted that 11 of the 53 species found on the Atlantic coast are identical with species in European waters, while 12 of the Atlantic coast species occur also on the Pacific coast and 2 of these extend also to Japan. No less than 18 of the species found on the Pacific coast are thought to be identical with well-known European species and others are closely similar (Coe, 1943). The nemertean fauna of Bermuda resembles more closely that of Europe and Madeira than that of the American coast in spite of the proximity of the latter.

As a general rule the invertebrates in the Gulf are much smaller when mature than are the members of the same species in more northern and colder localities. This applies likewise to the nemerteans. To anyone familiar with the species on the New England coast, the representatives of the same species in the Gulf appear to be dwarfs. Humes (1942) has described a dwarf variety of *Carcinonemertes carcinophila* from Louisiana, West Indies and eastern South America. Species living among bryozoa, algae and other growths in the intertidal zone farther north are more commonly found beyond the low-tide level in the Gulf. It is evident, however, that relatively few nemerteans

live beneath the deeper waters of the Gulf, for the records indicate that only two specimens were obtained during the dredging cruise of the U.S.F.C. Steamer ALBATROSS in 1885. One of these was a species of *Micrura,* while the other represented the genus *Cerebratulus* but they could not be further identified.

REPRODUCTION AND REGENERATION. If ripe individuals of both sexes are available, nearly all these species, but especially *Cerebratulus lacteus,* are suitable for the study of embryological development. From a large ripe female of *C. lacteus* several hundred thousand eggs may be obtained and these usually develop rapidly into pilidium larvae after artificial insemination. Most of the species restore by regeneration the posterior end of the body after injury or removal. *Lineus*

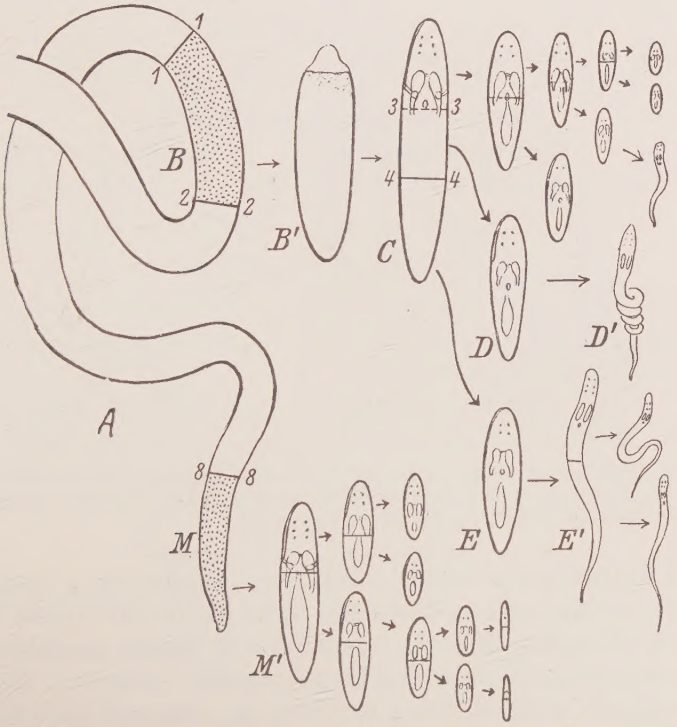

FIGURE 1. Regenerative capacity of body fragments of *Lineus socialis. A,* posterior part of mature worm; *B, C, D, E,* successive regeneration of portions of regenerating fragments when these are cut repeatedly as indicated; *M,* successive regeneration of fragment from posterior end of body.

socialis provides an example of asexual reproduction by fragmentation and is unexcelled for the study of the complete regeneration of minute fragments of the body. Coe (1929-1934) has shown that almost any small piece of the body, provided it contains a portion of one of the nerve cords, will regenerate into a minute replica of the original worm (Figure 1).

Ecology. Most of the species on the Gulf coast are found burrowing in the sand or mud in the low intertidal zone and below to areas where the depth of water is 10 to 20 meters or more. Others live beneath stones or among dead shells, while many of the smaller species occur among bryozoa, algae and other growths in the low intertidal zone and below.

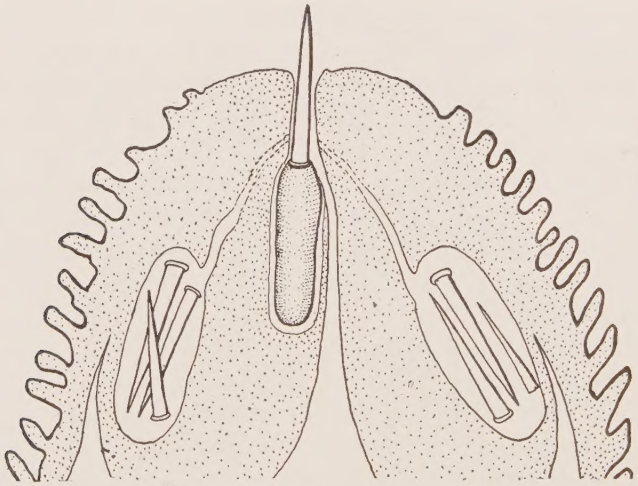

Figure 2. Diagram of fully everted proboscis of *Amphiporus cruentatus,* showing the acutely pointed stylet projecting at the end. The two pouches show newly formed stylets ready for replacement.

Food. Nemerteans are usually carnivorous, feeding on a great variety of worms, crustaceans, mollusks and other small, soft-bodied animals. To secure their prey they are furnished with highly specialized sense organs and most of them with a long, extrusible proboscis. This organ is a formidable weapon, being provided in some species with one or more acutely pointed stylets which puncture and paralyze the prey, allowing the soft parts to be sucked into the mouth (Figure 2). In species without stylets, the proboscis, which is covered with paralyzing

and tenacious secretions, can be coiled about the prey, thereby holding it tightly until it can be drawn into the mouth or held until the soft parts can be sucked out.

Because, as has been stated, the nemerteans of the northern Gulf coast are with few exceptions of different species than those found in southern Florida, those of the two areas will be treated in separate sections of this paper.

Geographical distribution of species at present known from the northern coast of the Gulf of Mexico

Abbreviations indicate: *A*, Atlantic coast of North America; *E*, coasts of Europe; *G*, northern coast of the Gulf of Mexico; *P*, Pacific coast of North America; *S*, southern Florida; *W*, West Indies; *X*, at other localities.

ORDER PALEONEMERTEA

Tubulanus pellucidus. *A,G,P.*
Carinoma tremaphoros. *A,G.*

ORDER HETERONEMERTEA

Zygeupolia rubens. *A,G.P.*
Lineus socialis. *A,G.*
Lineid sp?
Micrura leidyi. *A,G,S.*
Cerebratulus lacteus. *A,G.*

ORDER HOPLONEMERTEA

Paranemertes biocellata. *G.*
Carcinonemertes carcinophila. *A,E,G.*
Carcinonemertes carcinophila var. imminuta. *G,S,W.*
Oerstedia dorsalis, *A,E,G,P,X.*
Zygonemertes virescens. *A,G,P.*
Amphiporus cruentatus. *A,G,P.*
Amphiporus ochraceus. *A,G.*
Amphiporus texanus. *G.*
Amphiporus sp?
Tetrastemma candidum. *A,E,G, P,X.*
Tetrastemma vermiculus. *A,E,G.*

ORDER BDELLONEMERTEA

Malacobdella grossa. *A,E,G,P.*

Geographical Distribution of Species From Southern Florida

Abbreviations as in preceding list.

ORDER PALEONEMERTEA

Tubulanus floridanus. *S.*

ORDER HETERONEMERTEA

Baseodiscus delineatus. *E,P,S, W,X.*
Lineus ater. *S,W.*
Lineus stigmatus. *S.*
Micrura leidyi. *A,G,S.*
Cerebratulus fuscus. *E,S,X.*
Cerebratulus leucopsis. *S,W.*

ORDER HOPLONEMERTEA

Carcinonemertes carcinophila var. imminuta. *G,S,W.*
Drepanophorus crassus. *E,P,S, W,X.*

Because of the great differences in the ecological conditions between the coasts of northern and southern Florida, it is not surprising to find a more or less complete separation of the faunas. Only one of the species, *Micrura leidyi,* and the variety *imminuta* of *Carcinonemertes carcinophila* in the foregoing lists have been found in both regions. Hence it would appear that the nemerteans found at St. Augustine and Pensacola represent mainly northern forms, while those at Miami and Key West are principally tropical or subtropical species. In other groups of invertebrates likewise the species found in southern Florida are commonly more closely related with those of the West Indies and northern South America than with the fauna of the Atlantic coast north of Florida.

Section I

Key to the species at present known from the northern coast of the Gulf of Mexico, based mainly on easily recognizable external characteristics.

1. With suction disk at posterior end of body; commensal in bivalve mollusks 16
1. Without suction disk; not commensal in bivalves 2
2. Mouth posterior to brain; proboscis not armed with stylete 3
2. Mouth anterior to brain; proboscis with central stylet and in most species with 2 or more pouches of accessory stylets 8
3. Head without lateral longitudinal grooves 4
3. Head with lateral longitudinal grooves 6
4. Posterior end without slender caudal cirrus 5
4. Posterior end with long caudal cirrus; head acutely pointed *Zygeupolia rubens*
5. Body small, white; posterior end slender ..... *Tubulanus pellucidus*
5. Body when mature usually 30-150 mm long; red or yellowish red; posterior end broad and flattened ..... *Carinoma tremaphoros*
6. Body slender, rounded; head with 2 to 8 pairs small ocelli .. *Lineus socialis*
6. Body flattened in intestinal region; head without ocelli 7
7. Lateral margins rounded in intestinal region; not adapted for swimming; color dark red ..... *Micrura leidyi*

7. Lateral margins in intestinal region thin; adapted for swimming; color white, pale yellow or rosy ..... *Cerebratulus lacteus*
8. Proboscis with central stylet only and no accessory stylets; parasitic on crabs ..... *Carcinonemertes carcinophila*
8. With 2 or more pouches of accessory stylets; not parasitic 9
9. Proboscis with 4 or 8 pouches of accessory stylets; only one pair of ocelli *Paranemertes biocellata*
9. Proboscis with only 2 pouches of accessory stylets; head with more than one pair of ocelli 10
10. Ocelli numerous, extending posteriorly beyond head *Zygonemertes virescens*
10. Ocelli limited to head 11
11. More than 2 pairs of ocelli 12
11. Only 2 pairs of ocelli 14
12. Ocelli in a single row on each side of head; blood corpuscles red *Amphiporus cruentatus*
12. Ocelli in several groups or irregular rows; blood nearly colorless 13
13. Central stylet of proboscis rounded at both ends and slightly constricted in the middle ..... *Amphiporus ochraceus*
13. Central stylet truncated at both ends; not constricted in the middle *Amphiporus texanus*
14. Yellowish, without spots of dark pigment ..... *Tetrastemma candidum*
14. Body small, cylindrical; color variable; irregularly spotted with brown.. 15
15. Body short and firm; ocelli large, those of the same side not connected by band of pigment ..... *Oerstedia dorsalis*
15. Body soft, yellowish; the two ocelli of same side connected by band of dark pigment ..... *Tetrastemma vermiculus*
16. Body with suction disk at posterior end; commensal in bivalve mollusks *Malacobdella grossa*

Systematic Descriptions of Species

The following abbreviated descriptions of the species at present known from the northern coast of the Gulf are based mainly on easily recognizable external characteristics. The geographical range as given indicates the limits of the species in so far as at present known and should not be interpreted as implying that the species will not later be found elsewhere.

Order 1, PALEONEMERTEA

Family Tubulanidae

Tubulanus pellucidus Coe, 1940, 1943

Carinella pellucida Coe, 1895.

The minute worms belonging to this species may be recognized by their soft, slender, white bodies and by the absence of both ocelli and longitudinal grooves on the head (Figure 3). Length when mature 10 to 25 mm, width 1 mm or less.

The worms live in delicate cellophane-like tubes among algae and

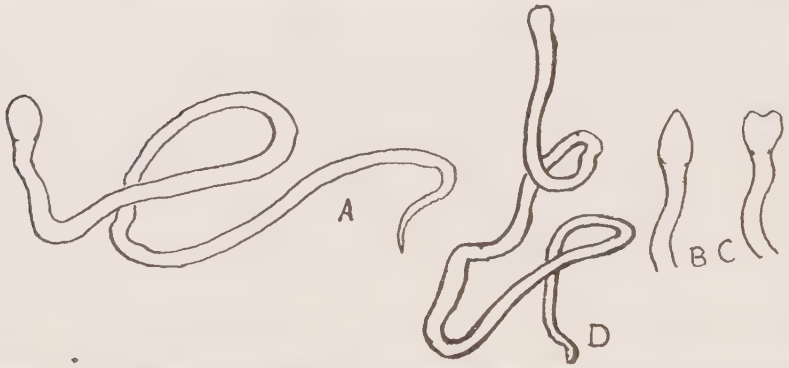

FIGURE 3. *Tubulanus pellucidus*. *A*, *D*, outlines of body; *B*, *C*, anterior ends in different states of contraction.

other growths in the intertidal zone and below to a depth of at least 20 meters. Recorded from southern New England to northern Florida on the Atlantic coast and has been found also at Pensacola, Florida, on the Gulf coast. It presumably occurs elsewhere along the Gulf coast. Found also from Monterey Bay to San Diego, California.

Family CARINOMIDAE

CARINOMA TREMAPHOROS Thompson, 1900; Coe, 1943

FIGURE 4. *Carinoma tremaphoros*. Outlines showing variations in shape of head in different states of contraction and the broad and flat posterior extremity of body.

Body pale reddish or yellowish, with broadened posterior end, which is without caudal cirrus. Head broad, without ocelli or longitudinal grooves (Figure 4). Length when mature 30 to 150 mm, width 2 to 5 mm. The worms burrow in mud, sandy mud and clay or live beneath

stones in the intertidal zone and below from Cape Cod to northern Florida and on the Gulf coast at least as far west as Louisiana.

Order 2, HETERONEMERTEA

Family Lineidae

Zygeupolia rubens Coe, 1905, 1940, 1943

Valencinia rubens Coe, 1895; *Zygeupolia litoralis* Thompson, 1900.

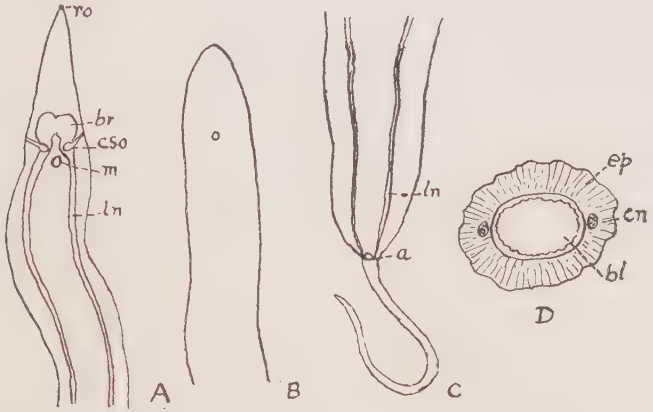

Figure 5. *Zygeupolia rubens. A, B,* diagrams of anterior portions of body of two individuals, one of which is extended and the other contracted. *C,* posterior end of body, showing long caudal cirrus with central blood space. *D,* transverse section of caudal cirrus, showing central blood space (*bl*), pair of caudal nerves (*cn*) and outer ciliated epithelium (*ep*). Other letters indicate: *a,* anus; *br,* brain; *cso,* cerebral sense organ; *ln,* lateral nerve cord; *m,* mouth; *ro,* rhynchodeal opening.

The worms of this species may be identified by the red or rosy color, sharply pointed head and long caudal cirrus (Figure 5). The head is white and usually sharply pointed in life but is rounded when strongly contracted. There are no ocelli or longitudinal grooves. Length 40 to 80 mm when mature; width 2 to 5 mm.

Found in sand or beneath stones in the intertidal zone and below from southern New England to northern Florida and on the Gulf coast westward to Copano Bay, Texas.

Lineus socialis Verrill, 1892; Coe, 1943

Nemertes socialis Leidy, 1855.

Recognized by the very slender body, with a row of 4 to 8 small ocelli on each side of head (Figure 9) and by the tendency of the

FIGURE 6. *Lineus socialis;* outline of body, showing coiled condition when strongly contracted.

worms to coil in spiral when disturbed (Figure 6). Length when mature 30 to 150 mm, width 1 to 3 mm. Color variable, often pale olive green, greenish brown or reddish brown; frontal margin and lateral borders of head whitish; brain region bright red; body sometimes encircled with 6 to 20 or more narrow and inconspicuous rings of lighter color.

These little worms live beneath stones and among mussels and other growths in the intertidal zone from Bay of Fundy to northern

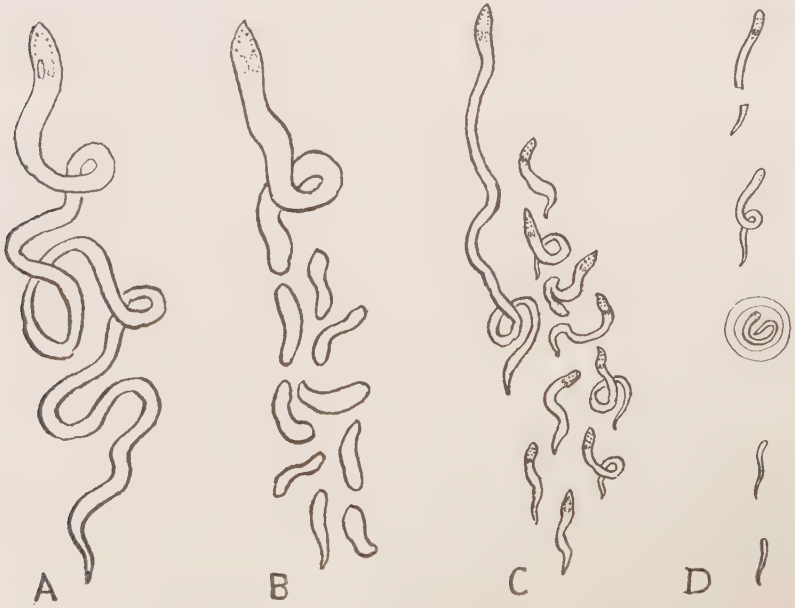

FIGURE 7. *Lineus socialis.* Diagram of asexual reproduction by natural fragmentation. *A*, mature worm; *B*, same after producing nine fragments; *C*, regeneration of each fragment, resulting in ten smaller worms of normal proportions; *D*, regeneration of minute fragments cut from body of regenerating fragment; one of these has formed a temporary cyst.

Florida and on the Gulf coast westward to Texas. Locally common and often gregarious.

This species differs from all others on this coast by its capacity for asexual reproduction by fragmentation (Figure 7). If the body be cut into many small pieces, each fragment will ordinarily regenerate into a minute replica of the original worm (Figure 1). Temporary encystment of small regenerating fragments often occurs (Figure 7). For complete regeneration the fragment must contain a portion of at least one of the nerve cords. This is excellent material for such studies, since the worms or their fragments may live for a year or more in jars of sea-water with pebbles in the bottom, provided the water be changed occasionally (Coe, 1929-1934). Furthermore various types of twinning may be produced by splitting a regenerating fragment at one or both ends. The twinned individuals eventually separate into two or more complete worms (Figure 8). A period of asexual reproduc-

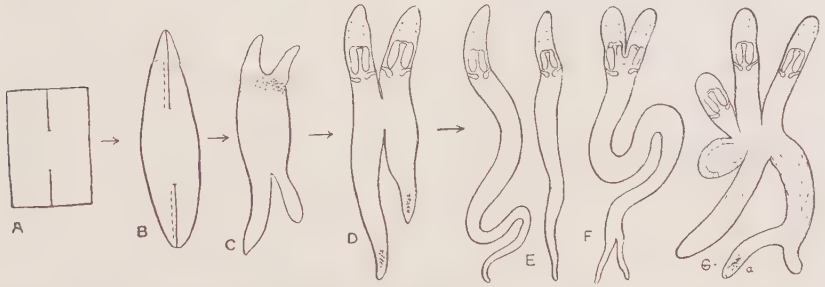

FIGURE 8. *Lineus socialis*. Twins produced by splitting regenerating fragment at both ends.

tion may be followed by dioecious sexual reproduction in which the sexes mate and the eggs are deposited in a thick mucous sheath.

The nephridial system, which has not been fully described heretofore, is peculiar in being divided into a short anterior portion on each side, separated by the mouth and anterior esophageal region from the more extensive posterior system. The anterior portion is limited to the short space on the lateral wall of the cephalic blood lacuna between the cerebral sense organ and the mouth. Here a comparatively large longitudinal canal lies in a narrow ridge on the wall of each of the lacunae and is thereby almost entirely surrounded by the blood (Figure 9). From the longitudinal canal the efferent duct leads to the

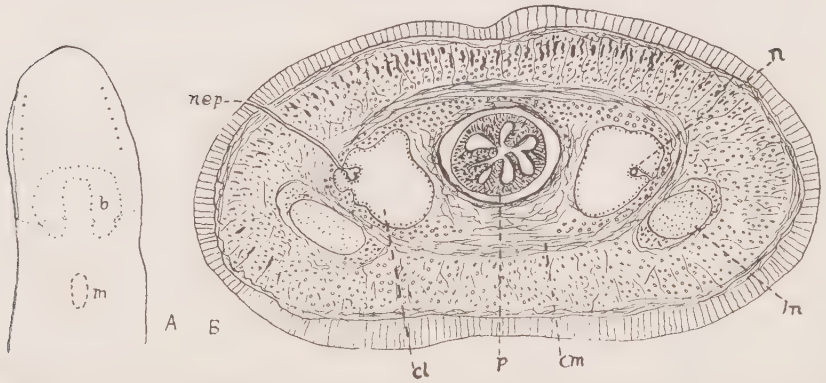

FIGURE 9. *Lineus socialis*. *A*, outline of head, showing position of the 7 pairs of ocelli, brain (*b*) and mouth (*m*). *B*, transverse section of head between brain and mouth, showing anterior pair of nephridial canals (*n*) projecting freely in lumens of cephalic blood lacunae (*cl*), with one of the pair of efferent nephridial ducts (*nep*) opening on the dorsolateral aspect of the head. Other letters indicate: *cm*, circular musculature; *ln*, lateral nerve cord; *p*, proboscis.

dorsolateral surface of the head posterior to the cephalic groove. In each of two specimens sectioned the efferent duct on the left side was near the posterior end of the longitudinal canal and that on the right side near the anterior end. A small number of flagellated terminal cells lie in the connective tissue bordering the lacunae.

The posterior portion of the nephridial system on each side is much more extensive and consists of a long, convoluted tubule in the usual position beside almost the entire length of the fore gut, with a multitude of terminal cells and several efferent ducts leading to the dorsolateral surfaces of the body.

In several other species of *Lineus*, notably *L. geniculatus* (D. Chiaje), *L. lacteus* Grube and *L. nigricans* Bürger, as well as in certain species of *Cerebratulus*, the nephridia likewise extend forward in ridges on the walls of the cephalic lacunae but in these cases the entire system on each side of the body is connected.

MICRURA LEIDYI (Verrill)

Meckelia rosea Leidy, 1851; *Cerebratulus leidyi* Verrill, 1892; *Micrura leidyi*, Coe, 1943.

This is one of the most common of the species of ribbon worms in the Gulf and along the east coast of the United States. The body

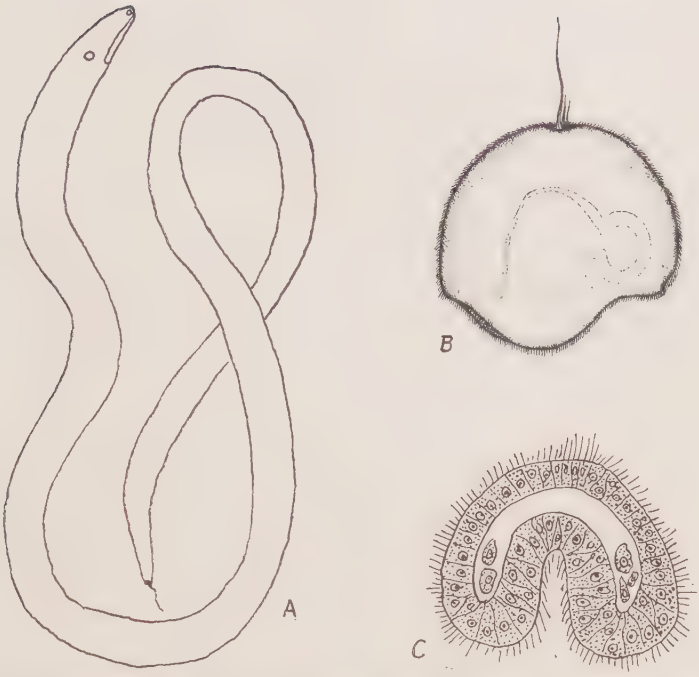

FIGURE 10. *Micrura leidyi*. *A*, outline of body, showing mouth, rhynchodeal opening and one of the cephalic grooves. *B*, early pilidium, with ciliated esophagus and primitive intestine. *C*, gastrula, with mesenchyme cells in cavity.

is rather slender, cylindrical in anterior portion and much flattened in intestinal region; very fragile; head slender, without ocelli; mouth small, caudal cirrus small (Figure 10).

Color deep red or purplish red, lighter anteriorly; anterior border of head and mouth region whitish. Length 20 to 200 mm, width 1 to 6 mm.

Lives in sand, sandy mud and under stones in the intertidal zone and in shallow water from Massachusetts Bay to the coast of northern Florida and in the Gulf at least as far west as Texas. In some localities on the northern Gulf coast it is more abundant than any other species of nemertean.

Individuals of this species are among the most fragile of all nemerteans and usually break into many pieces when lifted from the sand. The numerous eggs, which are excellent for embryological studies, are shed into the water from July to October on the coast of southern

New England, but the season of reproduction in the Gulf is not at present known. The larvae can be reared to the pilidium stage without difficulty (Figure 10). The adult worms have the capacity for the rapid posterior regeneration of fragments from the anterior part of the body but if the head be removed it is seldom, if ever, restored.

Micrura sp?

One specimen which the writer is unable to identify as belonging to any described species was dredged in 1885 at Station 2400 in the Gulf of Mexico at 28°41′ N. Lat., 86°07′ W. Long, in gray mud at a depth of about 510 meters. This locality is far offshore south of Cape San Blas.

The head is slender and rather sharply pointed anteriorly, with long cephalic grooves and is peculiar in having the rhynchodeal opening on the ventral surface some distance posterior to the tip of the head. The mouth is a small oval slit. The posterior end of the body is missing, but the fragments of the body that remain measure about 40 mm in length and 2 to 3 mm in width. The preservation is not satisfactory for microscopical study and the color remaining is uniformly brown.

Cerebratulus lacteus Verrill, 1892; Coe, 1943

Mecklia lactea Leidy, 1851; *M. ingens* Verrill, 1873.

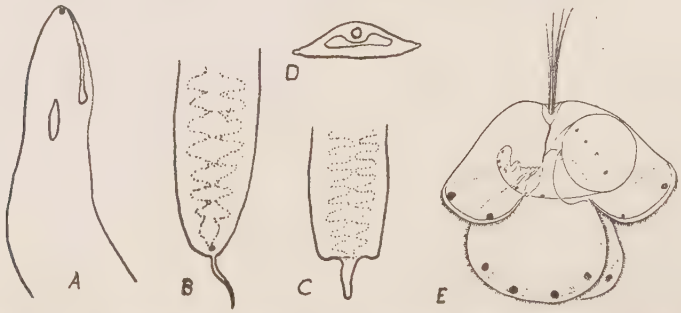

Figure 11. *Cerebratulus lacteus*. *A*, anterior end of body, showing the large mouth, subterminal rhynchodeal opening and one of the long cephalic grooves; *B*, posterior end with caudal cirrus; *C*, regeneration of posterior end of body; *D*, tranverse section through intestinal region, showing thin lateral margins; *E*, pilidium larva. (*E*, after Verrill.)

The body is long and ribbon-like, with flattened intestinal region and thin lateral margins; well adapted for swimming. Ocelli absent; caudal cirrus slender (Figure 11).

Mature individuals are larger than any of the other nemerteans at present known on the Gulf coast, often exceeding a meter in length. Color variable; whitish, pale yellow, flesh color, pale red or salmon. Young individuals are usually translucent white or pale yellow, with brown intestinal diverticula.

This is a common species, burrowing in the mud or sand in the intertidal zone from Maine to northern Florida and along the Gulf coast to Port Aransas, Texas.

Each large female produces each season many thousand translucent ova which are fertilized in the water and develop rapidly into pilidium larvae (Figure 11). The eggs of this species have been widely used in experimental studies and for class demonstrations. Posterior regeneration takes place readily but anterior regeneration is limited to the head anterior to the brain. With occasional changes of the sea-water and low temperature, a worm of this species, with or without head, may live for several months without food, the body meanwhile being reduced to a small fraction of its original size.

Order 3, HOPLONEMERTEA

Family Emplectonemertidae

Paranemertes biocellata Coe, 1944

This species may be recognized by the slender body, with sharply pointed head bearing a single pair of oval, black ocelli near the tip. The color of the body is pale green with a slightly rosy tinge. The proboscis is provided with a slender central stylet about two-thirds as long as the slender, cylindrical basis. There are either four or eight pouches of accessory stylets and 12 proboscidial nerves. Size when mature 60 to 120 mm in length and 2 to 4 mm in width. Details of organ systems are shown in Figure 12.

This species is at present known only from Biloxi, Mississippi, where it has been found burrowing in the intertidal sand flats and in shallow water.

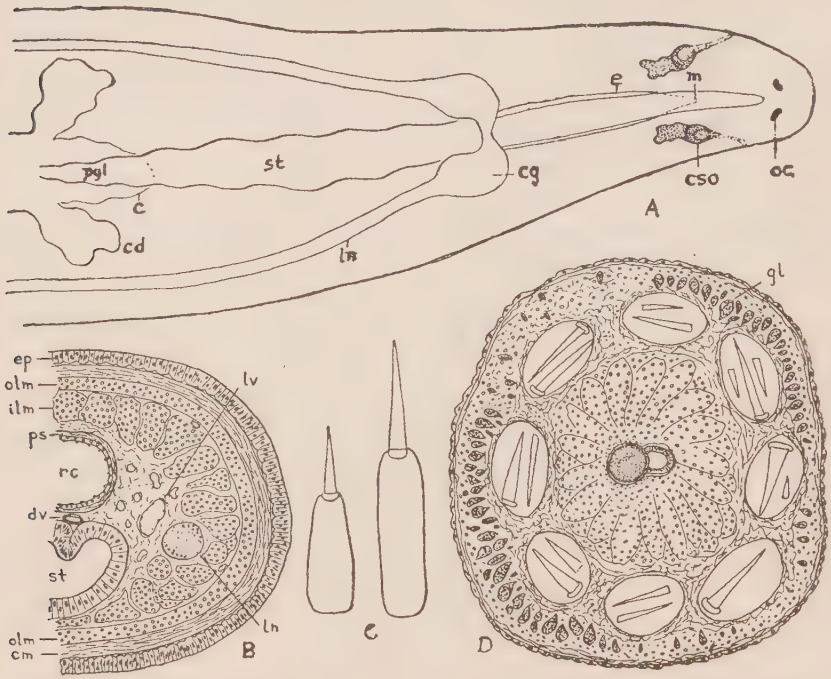

FIGURE 12. *Paranemertes biocellata. A,* diagram of organ systems in anterior end of body; *c,* caecum; *cd,* caecal diverticulum; *cg,* cerebral ganglion; *cso,* cerebral sense organ; *e.* esophagus; *ln,* lateral nerve cord; *m,* opening of mouth into rhynchodeum; *oc,* ocellus; *pyl,* pylorus; *st,* stomach. *B,* portion of transverse section of body posterior to brain, showing the two layers of longitudinal muscles; *cm,* circular muscular layer; *dv,* dorsal blood vessel; *ep,* epithelium of body wall; *ilm,* inner layer of longitudinal muscles; *ln,* lateral nerve cord; *lv,* lateral blood vessel; *olm,* outer layer of longitudinal muscles; *ps,* proboscis sheath; *rc,* rhynchocoel; *st,* stomach. *C,* central stylet and basis from two individuals. *D,* diagram of transverse section through septum of proboscis, showing, in center, stylet basis and canal leading from anterior to posterior proboscis chamber, and longitudinal musculature surrounded by eight pouches of accessory stylets; *gl,* wreath of pigmented gland cells.

Family Carcinonemertidae

Carcinonemertes carcinophila Coe, 1902

Nemertes carcinophilon Kolliker, 1845; *C. carcinophila* Humes, 1941, 1942.

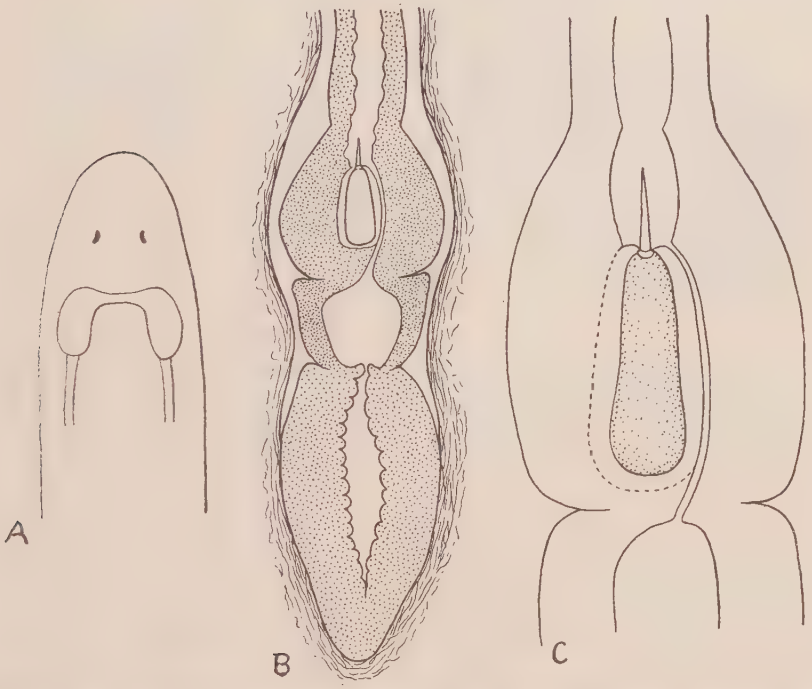

Figure 13. *Carcinonemertes carcinophila*. *A*, outline of head, showing brain and ocelli. *B*, proboscis, with posterior chamber immovably attached to proboscis sheath. *C*, middle portion of proboscis with stylet on elongated basis and canal leading from anterior to posterior chamber.

These curious little nemerteans are parasitic on the gills of various species of crabs when young and during the season when the crabs are without eggs. They migrate to the egg-masses of the host as soon as these are produced. Reproduction occurs only when on the egg-masses.

The slender body, 20-70 mm in length, is colored in various shades of red; there is a single pair of ocelli on the head. The proboscis is very short and can be extended only as far as the tip of the head; it has a slender central stylet and basis but no accessory stylets (Figure 13).

In this genus the sexes are separate, the numerous ovaries being of

the usual hoplonemertean type, while the male reproductive organs differ from those known for any other nemerteans. The numerous spermaries connect with a single longitudinal spermatic duct which opens into the posterior portion of the rectum (Figure 14). At the

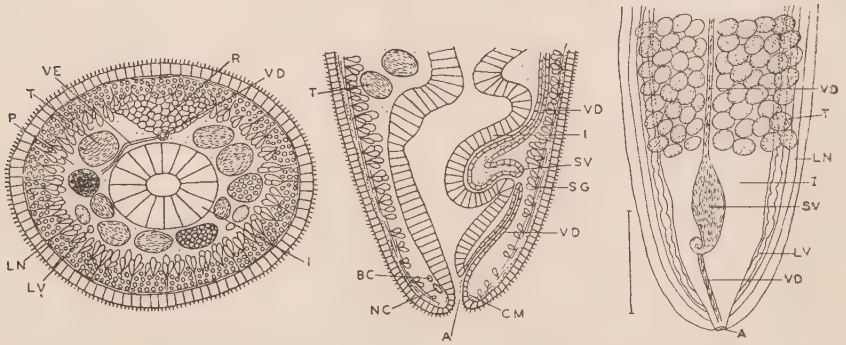

FIGURE 14. *Carcinonemertes carcinophila.* Diagrams of transverse and longitudinal sections of body of male, showing the numerous spermaries (*T*), with seminal vesicle (*SV*) and common efferent duct (*VD*) opening into the intestine near the anus (*A*). Other letters indicate: *I,* intestine; *LN,* lateral nerve cord; *LV,* lateral blood vessel; *SG* submuscular glands. (From Humes, 1942).

time of reproduction a male and a female place their bodies side by side and secrete a thick sheath of mucus in which a hundred or more relatively large eggs are deposited. Development is of the direct type. The morphology and biology of this species are fully described by Humes (1942).

Crabs of the family Portunidae, particularly the lady crab (*Ovalipes ocellatus*) and the blue crab (*Callinectes sapidus*) on the American Atlantic coast and *Carcinides maenas* in European waters are most frequently infested. On the Gulf coast *Callinectes sapidus* is the usual host but representatives of other families are occasionally infested (Humes, 1942). With the needle-like central stylet the young worms presumably puncture the gills of the host and suck out the blood, while the adults similarly puncture the eggs of the host and devour the contents, whether yolk or embryo. It seems probable that additional food for both young and adult is obtained from such small animals as may be encountered.

Found on the Atlantic coast from the Bay of Fundy to Florida and along the Gulf coast to Texas, as well as on European shores from Scotland to the Mediterranean.

Carcinonemertes carcinophila, var. immunuta Humes, 1941, 1942

This variety differs from the typical form in being of smaller size when mature, in having a shorter and more slender stylet basis, a shorter stylet and in other minor morphological details. This variety was more abundant on *Callinectes sapidus* than on any other crabs at Grand Isle, Louisiana, and on other species in the West Indies, Panama and Brazil.

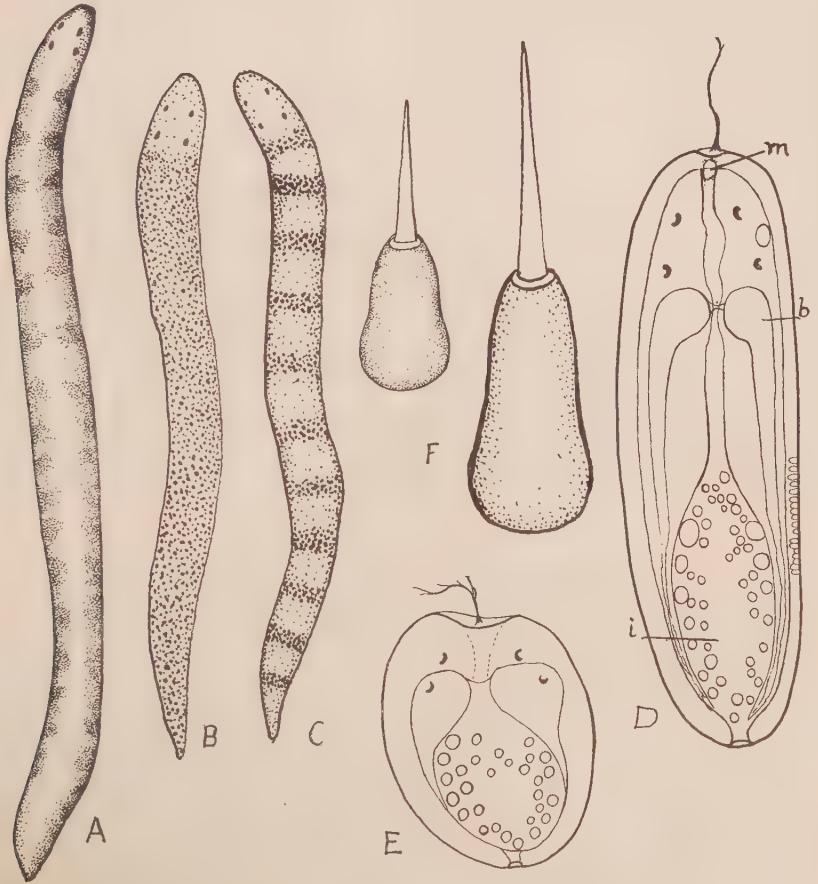

Figure 15. *Oerstedia dorsalis*. *A, B, C,* three of the many variations in color patterns; *D,* embryo with direct type of development, showing mouth (*m*), intestine (*i*), brain (*b*), and the four large ocelli; *E,* same when contracted; *F,* variations in size of central stylet and basis in small and large individuals.

Family Prosorhochmidae

Oerstedia dorsalis Bürger, 1895; Coe, 1940, 1943

Planaria dorsalis Abildgaard, 1806; *Tetrastemma dorsale* Verrill, 1892.

Individuals of this widely distributed species may be recognized by their small cylindrical, firm bodies, often brightly colored and spotted or banded in conformity with their environment. They have a superficial resemblance to species of *Tetrastemma* and the same number of ocelli but the body is relatively shorter, firmer and less flattened. They are also less active in their movements.

Mature individuals seldom exceed 10 to 20 mm in length and 1 to 2 mm in diameter. The head bears 4 rather conspicuous ocelli. Proboscis relatively large; provided with slender stylet on pear-shaped basis and 2 pouches of accessory stylets (Figure 15.) The colors are extremely variable, with shades of red, brown, olive, whitish or yellowish and spotted, banded or striped with more deeply colored pigment (Figure 15).

Locally abundant among algae, bryozoa and other growths on rocks and piles in the low intertidal zone and below on the coasts of Europe to Madeira; on the Atlantic coast of North America from Nova Scotia to northern Florida; on the Gulf coast westward to Texas; and on the Pacific coast from Puget Sound to Mexico. The relatively large eggs undergo the direct method of development (Figure 15).

Family Amphiporidae

Zygonemertes virescens Montgomery, 1897; Coe, 1940, 1943

Amphiporus virescens Verrill, 1879, 1892; *Ophionemertes agilis* Verrill, 1873; *Amphiporus agilis* Verrill, 1892.

The slender, cylindrical, greenish worms belonging to this species differ from all others known from the region in having very numerous minute ocelli which extend along the sides of the body far posterior to the brain (Figure 16). Living individuals may also be distinguished from those of other species by their restless, rapid movements. The proboscis sheath extends the entire length of body and the proboscis is armed with a slender central stylet with massive basis truncated posteriorly (Figure 16) and with 2 lateral pouches usually containing 3 accessory stylets each. Length of body when mature 10 to 40 mm, width 1 to 2 mm.

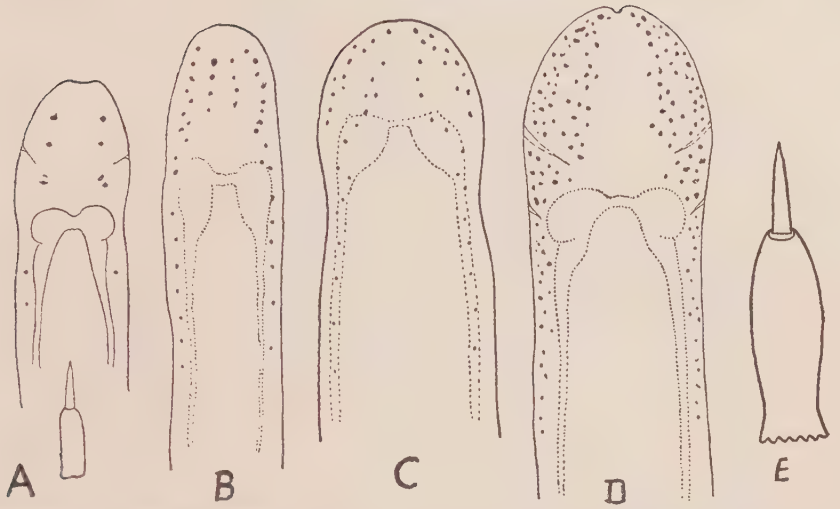

FIGURE 16. *Zygonemertes virescens.* Variations in the number and arrangement of ocelli and in size of central stylet and basis in young and older individuals; the stylet basis in *A* and *E* are drawn at the same scale of magnification.

The species is locally common among algae, bryozoa and other growths on rocks and other objects in the low intertidal zone and below. It occurs from the Bay of Fundy to northern Florida and along the Gulf coast at least as far as Pensacola, Florida. It is also found on the Pacific coast from British Columbia to Mexico.

AMPHIPORUS CRUENTATUS Verrill, 1879; Coe 1940, 1943
Amphiporus leptacanthus Coe, 1905.

Individuals of this species are easily recognized in life by their pale yellow color, with three slender longitudinal red lines representing the longitudinal blood vessels, as well as by the single row of 5 to 10 ocelli on each side of the head (Figure 17). Central stylet of proboscis long and slender, on long, slender basis (Figure 2, 17). Length when mature 10 to 30 mm, width 1 to 4 mm. Blood corpuscles bright red.

Lives among algae, bryozoa and other growths on rocks and beneath stones and shells in the intertidal zone and below from New England to northern Florida and on the Gulf coast at least as far as Pensacola, Florida, as well as on the Pacific coast from Puget Sound to Mexico.

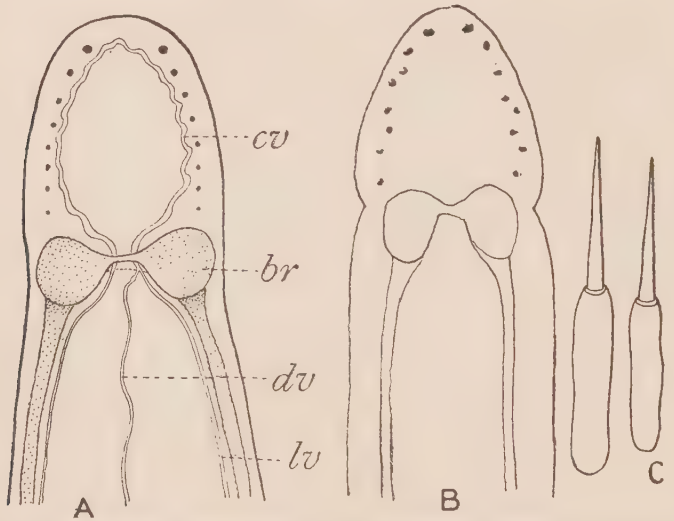

FIGURE 17. *Amphiporus cruentatus*. *A*, diagram of anterior end of body, showing brain (*br*), cephalic (*cv*), dorsal (*dv*) and lateral (*lv*) blood vessels and arrangement of ocelli; *B*, head with larger ocelli; *C*, variations in central stylets and bases.

This is a good species for the study of posterior regeneration, the restoration of a lost proboscis, and the reorganization of fragments cut from the anterior portion of the body.

AMPHIPORUS OCHRACEUS Verrill, 1892; Coe, 1943

Cosmocephala ochracea Verrill, 1873; *A. greemani* Montgomery, 1897.

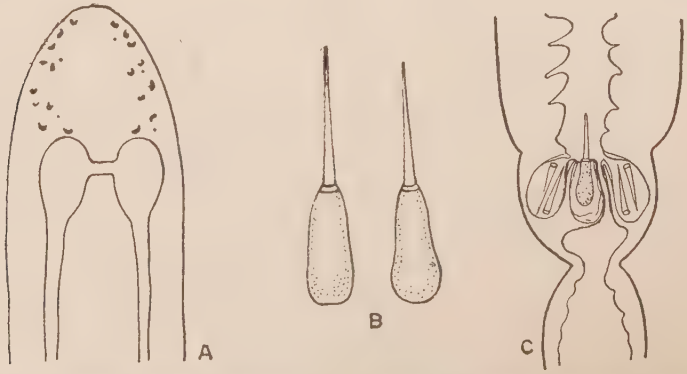

FIGURE 18. *Amphiporus ochraceus*. *A*, outline of head, showing arrangement of ocelli; *B*, central stylets and bases; *C*, middle chamber of proboscis, with armature.

In this species the body is slender and yellow, whitish or grayish in color, sometimes with tinge of orange anteriorly and occasionally with brown intestinal diverticula. The length when mature varies from 10 to 70 mm and the width 1 to 3 mm. The head bears 6 to 14 small ocelli in irregular rows on each lateral margin, bending medially toward the brain (Figure 18). The proboscis has a slender central stylet and basis, with usually two accessory stylets in each of the two pouches (Figure 18).

Locally common beneath stones and among algae and other growths in the intertidal zone and below from Massachusetts Bay to Florida and in the Gulf westward to Port Aransas, Texas.

Amphiporus texanus Coe, 1951

This species represents one of the larger and broader forms of this extensive genus. The type specimen was about 60 mm in length and 6 mm in width after preservation. The length of this specimen is therefore only 10 times the greatest width. The head is narrow, about 2 mm in width, with subterminal mouth and transverse or oblique lateral

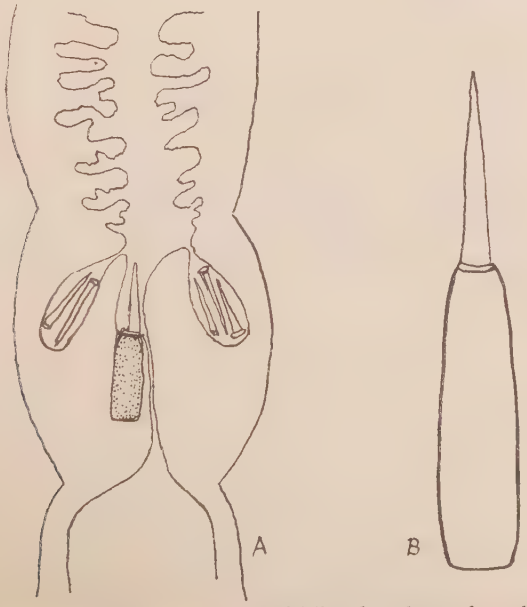

Figure 19. *Amphiporus texanus. A,* middle chamber of proboscis, with armature; *B,* central stylet and basis.

grooves. There are many small ocelli on each side of the head, although the exact number and arrangement have not been determined.

The proboscis is large and extends nearly the entire length of the body. The central stylet is moderately slender and about two-thirds as long as the relatively massive basis. The latter is nearly rectangular in outline, about four times as long as its diameter, tapering but slightly toward the anterior end and is truncated posteriorly (Figure 19.) There are two pouches of accessory stylets and 10 rather large proboscidial nerves.

No record is available regarding the color in life, but the specimen preserved in formalin indicated a pale, reddish brown epidermal pigmentation.

The cerebral sense organs are comparatively larger than in most species of the genus. They are situated lateroventrally and a short distance anterior to the brain.

At present known only from the type specimen which was collected at Port Aransas, Texas.

Amphiporus sp?

Among the nemerteans collected by Don Carpenter at Alligator Bay, Franklin County, Florida, was one specimen of a species of *Amphiporus* which apparently represents an undescribed species but for which no satisfactory diagnosis can now be supplied because of the absence of the proboscis.

The body is fusiform and moderately slender, measuring after preservation 18 mm in length and 2 to 3 mm in width. The color after preservation is milk white. The head is provided with a row of 10 remarkably large ocelli on each lateral border and a group of 5 smaller ocelli on each side situated more posteriorly and nearer the median line. Mouth and rhynchodeal opening in close contact. Cerebral sense organs large, situated beside and behind brain with large canals to lateral borders of head.

Family TETRASTEMMATIDAE

TETRASTEMMA CANDIDUM McIntosh, 1873,
Verrill, 1892; Coe, 1940, 1943
Fasciola candida Müller, 1774.

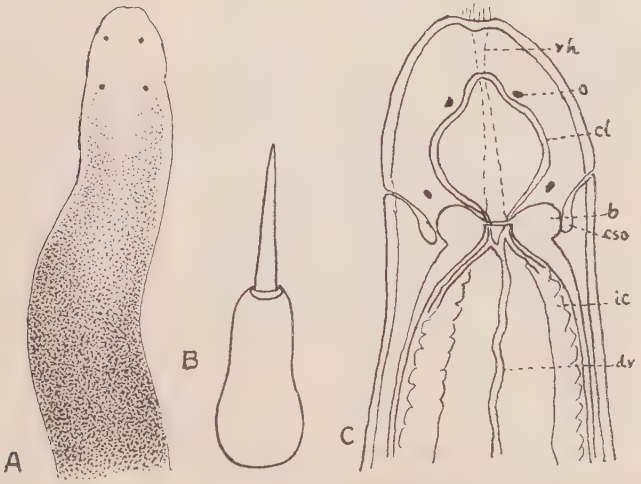

FIGURE 20. *Tetrastemma candidum. A,* anterior end of body, showing ocelli and pigmentation; *B,* central stylet and basis; *C,* diagram of organ systems; *b,* brain; *cso,* cerebral sense organ; *cl,* cephalic lacuna; *dv,* dorsal blood vessel; *ic,* intestinal caecum; *o,* ocellus; *rh,* rhynchodeum.

These little worms (Figure 20) may be identified by the pale green or yellowish green body without markings. Young individuals are pale yellow laterally and green medially. There are 2 pairs of conspicuous reddish brown ocelli anterior to the brain (Figure 20). The stylet basis is rounded at both ends and slightly enlarged posteriorly (Figure 20). Length of the body when mature 10 to 20 mm, occasionally 35 mm; width 0.5 to 1.5 mm.

Locally common among bryozoa, algae and other growths in the intertidal zone and below from Labrador to northern Florida and on the Gulf coast at least as far west as Louisiana. Found also on European coasts, Madeira and South Africa, as well as on the Pacific coast from Alaska to Mexico. This is a typical circumpolar species.

TETRASTEMMA VERMICULUS Stimpson, 1857; Verrill, 1892; Coe, 1943
Polia vermiculus Quatr., 1846.

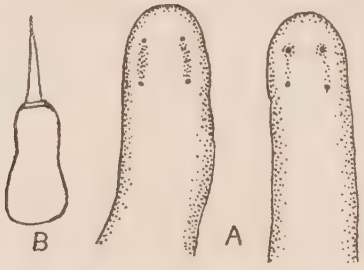

FIGURE 21. *Tetrastemma vermiculus. A,* outlines of the heads of two individuals, showing variations in the width of the longitudinal band of pigment connecting the two ocelli of the same side. *B,* central stylet and basis.

This species resembles *T. candidum* in many respects but differs in having a whitish, light yellow or pale reddish body and in having the two ocelli of the same side conected by a narrow band of dark pigment (Figure 21). A narrow ring of pigment often surrounds the anterior ocelli. The body is slender and seldom more than 15 to 20 mm long and 1 mm wide.

The proboscis is longer than the body and is provided with a relatively large basis somewhat constricted near the middle and slightly longer than the stylet (Figure 21). There are two pouches of accessory stylets and ten proboscidial nerves. The cerebral sense organs are relatively large and are situated anteroventrally to the brain.

Locally common among algae and bryozoa in the intertidal zone and below from the Bay of Fundy to northern Florida and on the Gulf coast westward to Texas. Found also on European coasts from Norway to Madeira.

Order 4, BDELLONEMERTEA

Family MALACOBDELLIDAE

MALACOBDELLA GROSSA (O. F. Müller), 1776

M. grossa Bürger, 1895; Gering, 1911; Riepen, 1933; Coe, 1940; *M. obesa, M. mercenaria* Verrill, 1892.

Body short and broad, wider at posterior end which bears a comparatively large suction disk (Figure 22).

Length when mature 20 to 40 mm, width 8 to 15 mm. Color white, gray, pale yellow or brownish. Ocelli and cerebral sense organs absent. Alimentary canal narrow, cylindrical and convoluted; without diverti-

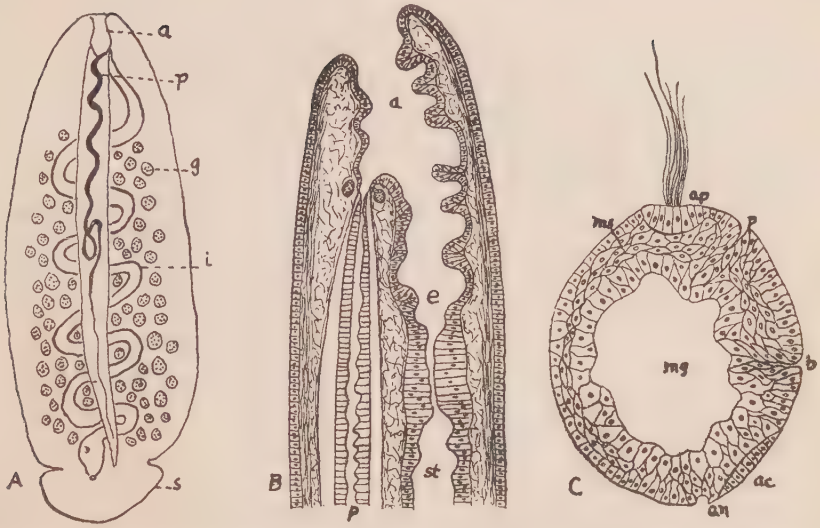

FIGURE 22. *Malacobdella grossa. A,* outline of internal organs; *a,* atrium; *g,* one of the numerous gonads; *i,* convoluted intestine, with rectum and anus at base of suction disk; *p,* proboscis in proboscis sheath; *s,* suction disk. *B,* sagittal section through anterior end of body, showing atrium (*a*), esophagus (*e*), stomach (*st*) and attachment of phoboscis (*p*). *C,* larva with apical tuft of flagella (*ap*), invaginating proboscis (*p*), blastopore (*b*), midgut (*mg*), anus (*an*) and primordium of suction disk (*ac*). (*C,* after Hammersten.)

cula (Figure 22). Proboscis slender, with weak musculature and without stylets. Gonads in both sexes small and numerous. Eggs that are artificially fertilized develop rapidly without metamorphosis (Figure 22).

Commensal in the mantle cavity of various species of bivalve mollusks; on the Atlantic and Gulf coasts more commonly in *Venus mercenaria* than in any other species. Widely distributed on European shores as far south as the Mediterranean; on the American Atlantic coast from Nova Scotia to Florida, on the Gulf coast westward to Texas and on the Pacific coast as far south as California. It probably causes little, if any, injury to the host, since it feeds mainly on the larger particles which the mollusk draws into its mantle cavity but does not ingest.

Section 2.

Key to species at present known from southern Florida

1. Proboscis without stylets, mouth posterior brain 2
1. Proboscis with one or more stylets; mouth anterior to brain 8
2. Head with a pair of lateral longitudinal grooves 4
2. Head without longitudinal grooves 3
3. Body brown, encircled by many rings of lighter color; lateral nerve cords external to musculatures; cutis thin or absent ..... *Tubulanus floridanus*
3. Body light brown, without rings, but marked by numerous short, interrupted longitudinal lines of dark brown; lateral nerve cords internal to external longitudinal muscular layer; cutis thick ... *Baseodiscus delineatus*
4. Mouth small; body rounded in intestinal region; not adapted for swimming 5
4. Mouth large; lateral margins of body in intestinal region thin; adapted for swimming 7
5. Color red or rosy; body with slender caudal cirrus ..... *Micrura leidyi*
5. Color brown or black; body without caudal cirrus 6
6. Color black, with pale anterior border of head ..... *Lineus ater*
6. Color brown, with numerous paired transverse white markings on dorsal surface ..... *Lineus stigmatus*
7. Color grayish blue or purplish with white anterior end; body slender throughout ..... *Cerebratulus leucopsis*
7. Color grayish brown or rosy with numerous darker flecks on dorsal surface; body widest posteriorly ..... *Cerebratulus fuscus*
8. Minute, slender, with single pair of conspicuous ocelli; parasites on crabs; stylet basis conical ..... *Carcinonemertes carcinophila imminuta*
8. Broad and flat, with numerous ocelli; not parasitic; stylet basis crescentic *Drepanophorus crassus*

Order 1, PALEONEMERTEA

Family Tubulanidae

Tubulanus floridanus Coe, 1951

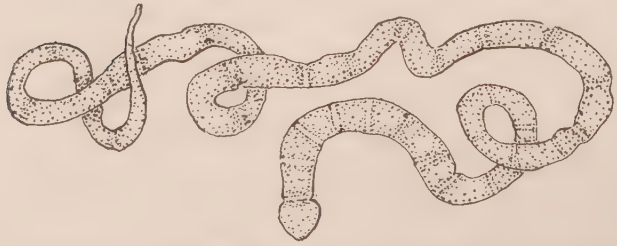

Figure 23. *Tubulanus floridanus*. Outline of body, showing narrow transverse whitish markings.

Body slender; the type specimen was 40 mm in length and only 1 to 2 mm in width after preservation. Head broad and flattened.

Color brown, with a series of very narrow rings, most of which

completely encircle the body (Figure 23). In a worm 40 mm in length there were 30 rings. Anteriorly the rings are separated by a distance about equal to the diameter of the body but more posteriorly they are generally more widely separated and irregularly spaced.

The cerebral sense organs are large and the sensory cells are well demarcated from the adjacent spithelium. Median dorsal nerve larger than in most species of the genus.

At present known from only a single specimen collected on a dock piling in Biscayne Bay, Florida.

Individuals of this species have a superficial resemblance to those of *T. annulatus* (Montague), *T. capistratus* Coe and *T. nothus* Bürger but are without longitudinal lines of contrasting color.

Family Baseodiscidae

Baseodiscus delineatus (Delle Chiaje)

Polia delineata Della Chiaje, 1923-1929; *Baseodiscus delineatus* Diesing, 1850; *Eupolia delineata* Hubrecht, 1887; Bürger, 1890, 1895.

This species may be recognized in life by the extremely slender, but not fragile, body with broadly rounded head which is normally well demarcated from body (Figure 24). The length may sometimes

Figure 24. *Baseodiscus delineatus*. Outline showing extremely slender body and linear markings when fully extended. (After Bürger, 1895).

exceed 500 mm but the width is seldom more than 2 mm except when the body is strongly contracted. A length of more than a meter has been reported.

Color of body, including head, varies from light to dark brown, sometimes with greenish tinge, thickly covered with short, slender

lines or interrupted longitudinal markings of darker shade both dorsally and ventrally (Figure 24, 25). Many variations of the color pattern have been reported. In addition to the typical form in which the lines are conspicuous, there are others in which the markings consist of indistinct and irregular rows of elongated dots.

Furthermore there is the broader and shorter form, *curtus,* considered by some to be a distinct species, in which the general coloration of the body varies from gray to deep red and the markings are indistinct. And finally there are individuals in which the ventral surface is colorless. In many widely separated localities the typical form and *curtus* are associated.

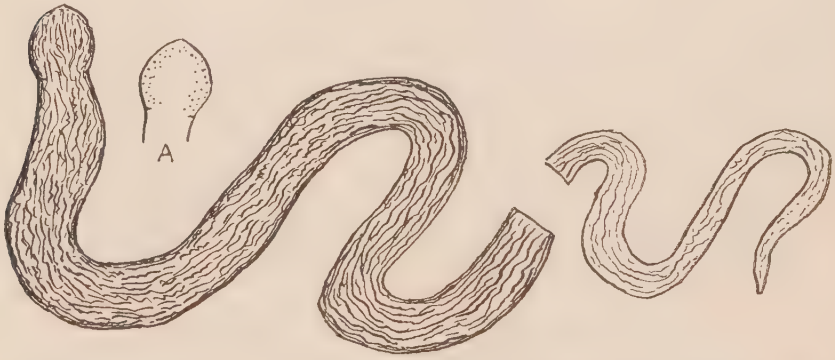

FIGURE 25. *Baseodiscus delineatus.* Outline of anterior and posterior ends of body, showing slender linear markings. *A*, head with numerous minute ocelli.

B. delineatus appears to be more widely distributed and in many places more abundant than any other species of nemertean, for it has been reported from the shores of nearly all the tropical and subtropical lands and islands where nemerteans have been collected. It occurs both in the northern and southern hemispheres, including the Mediterranean and Adriatic seas; Cape Verde Islands; Mauritius; Fifi Islands; Chile; Japan; Gulf of California; east coast of Africa; Java and other East Indian islands, Polynesia, Puerto Rico, Bermuda, Barbados, and the *curtis* form in Curaçao. On the Florida coast it has been found in Biscayne Bay.

Family Lineidae

lineus ater (Girard)

Meckelia atra Girard, 1851; *Cerebratulus ater* Verrill, 1895; Stiasny-Wijnhoff, 1925; Coe, 1943.

This species was originally described from a single specimen dredged in deep water off the Cape of Florida. Two headless fragments which may have belonged to the same species were reported by Stiasny-Wijnhoff from Curaçao. The body is uniformly black in color except for the pale anterior extremity.

In the collections of the United States National Museum is a complete specimen 120 mm long and 4 to 6 mm wide. This was collected by Henry Hemphill on a reef at Key West, Florida, in January, 1885. In spite of its long preservation it still shows the characteristics of the species as described by Girard and obviously represents one of the relatively short and broad species of *Lineus*. The head and cephalic grooves are short but the mouth is rather large. The body is rounded in the intestinal region and does not have the thin lateral margins characteristic of *Cerebratulus*. Since the internal anatomy of this species is still unknown, it is regrettable that the state of preservation of this specimen makes it unsuitable for microscopical study.

lineus stigmatus Coe, 1951

Figure 26. *Lineus stigmatus*. Diagram of posterior portion of body, showing arrangement of the paired white markings on dorsal surface.

Body rather slender, sometimes reaching a length of 150 mm or more and a width of 2 to 5 mm.

Color in life slaty brown on both dorsal and ventral surfaces, with paired transverse white markings on dorsal surface at intervals which

average about half the width of the body (Figure 26). Each narrow marking is about one-fifth the width of the body in length and the two members of each pair are separated from the margin of the body and from each other by about the same distance. These markings become irregularly spaced and indistinct toward the posterior end of the body. The colors are retained after preservation for some weeks in alcohol.

Transverse sections of the body show an unusually thick cutis with many spiral muscular fibers and a heavily pigmented layer externally.

The color pattern in this species has a superficial resemblance to that of some individuals of *L. geniculatus* (D. Chiaje) in which the white rings are interrupted in the mid dorsal line but in the latter species the rings continue laterally and ventrally. There is also some resemblance to *L. albocinctus* Verrill, recorded from Bermuda and Puerto Rico, although in that species the transverse lines are continuous on the dorsal surface and the ventral surface of the body is whitish.

The species is at present known only from the shore of Biscayne Bay, Florida.

MICRURA LEIDYI (Verrill)

See preceding section.

CEREBRATULUS FUSCUS (McIntosh)

Micrura fusca McIntosh, 1873-4; *Cerebratulus fuscus* Bürger, 1892, 1895, 1904 (not *C. fuscus* Verrill, 1892).

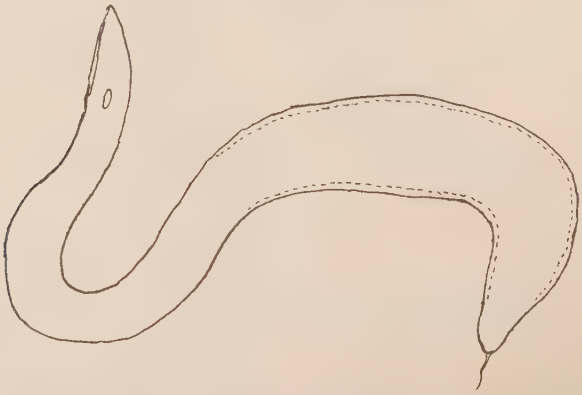

FIGURE 27. *Cerebratulus fuscus.* Outline of body, showing slender anterior portion and much wider posterior portion with caudal cirrus at end. The mouth and one of the cephalic grooves are indicated. Intestinal region with thin lateral margins adapted for swimming.

Differs from most other nemerteans in having the body slender anteriorly and much wider toward posterior end which is often sharply truncated in life but rounded when contracted. With slender caudal cirrus (Figure 27). Length of body 20 to 60 mm, width 2 to 6 mm. Head slender, not demarcated from body, with long cephalic grooves and large oval mouth.

Color grayish brown, flesh color or rosy, with pale lateral margins. Dorsal surface thickly speckled with more or less conspicuous dark flecks. Head with a yellowish or rosy hue.

Lives among algae, bryozoa and other growths in the lowest intertidal zone and below to depths of 100 meters or more. With a wide geographical distribution but most abundant on the coasts of England, Scotland, France and the Mediterranean. Reported also from South Africa. On the Florida coast this species has been found in Biscayne Bay.

In *C. luridus* Verrill, which occurs in deep water along the Atlantic coast from Nova Scotia to southern New England, the body is of similar shape but the two species differ widely in coloration and markings.

Cerebratulus leucopsis (Coe)

Micrura leucopsis Coe, 1902; Stiasny-Wijnhoff, 1925.

This species may be recognized by the grayish blue or purplish color of the body, with paler head and white anterior end. The body has smooth outlines, without corrugations when contracted; rounded in esophageal region and somewhat flattened posteriorly, with thin lateral margins. Length 50 to 100 mm. or more, width 3 to 6 mm.

Head narrower than body, roundly pointed anteriorly; cephalic grooves long and deep; mouth large. Caudal cirrus rather small; proboscis long and slender. No ocelli have been detected. The internal anatomy has been described by Coe (1902) and Stiasny-Wijnhoff (1925).

This appears to be a common and typical tropical species at depths of 20 meters or more. Four specimens were reported by Coe (1902) from Puerto Rico and seven by Stiasny-Wijnhoff (1925) from Curaçao. One specimen in the United States National Museum was collected by the U.S.F.C. Steamer ALBATROSS near Key West.

Order 3, HOPLONEMERTEA

Family CARCINONEMERTIDAE

CARCINONEMERTES CARCINOPHILA, var. IMMINUTA Humes, 1942

See section 1.

Family DREPANOPHORIDAE

DREPANOPHORUS CRASSUS (Quatr.)

Cerebratulus crassus Quatr., 1846; *D. crassus* Bürger, 1895; Coe, 1901; *Paradrepanophorus crassus* Stiasny-Wijnhoff, 1926.

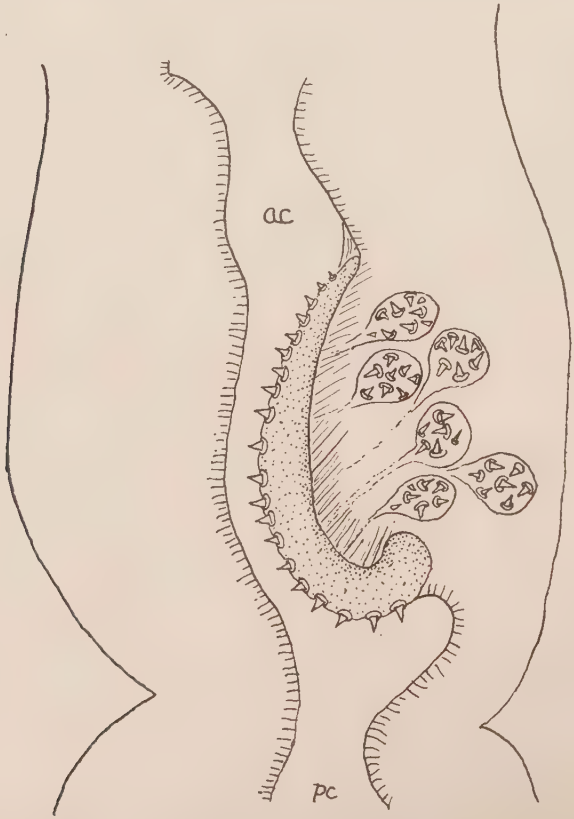

FIGURE 28. *Depanophorus crassus*. Diagram of armature of proboscis, showing sickle-shaped basis bearing 20 peg-like stylets and six of the pouches of accessory stylets. Anterior (*ac*) and posterior (*pc*) chambers of proboscis are indicated.

Body short, broad and much flattened; head narrow and usually well demarcated from body; mouth and rhynchodeal opening separate; proboscis sheath provided with lateral diverticula situated on dorsal side of intestinal diverticula, alternating with gonads; cerebral sense organs large, situated close beside and somewhat posterior to dorsal ganglia; lateral nerve cords lie on ventral side of body. Numerous large ocelli are arranged in two rows on each side of head.

Length of body when mature 20 to 50 mm, width 4 to 6 mm. Color of dorsal surface orange or yellow; ventral surface pale. Proboscis large, armed with sickle-shaped basis bearing about 20 peg-shaped stylets and a dozen or more pouches of accessory stylets (Figure 28). These are 19 or 20 proboscidial nerves.

This species has been reported from many tropical and subtropical seacoasts and elsewhere, including English Channel, Mediterranean Sea, Madeira, Samoa, Mauritius, Panama, Gulf of California, Peru and Puerto Rico but Stiasny-Wijnhoff (1926) has shown that some of these records actually pertain to other species. Found also near Key West, Florida.

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DISTRIBUTION OF VERTICAL WATER MOVEMENT CALCULATED FROM SURFACE DRIFT VECTORS[1]

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ABSTRACT

A simple method of calculating vertical water movements from the charted surface drift vectors is described. Application of this method to the Gulf of Mexico shows the presence of major year-round areas of convergence in the northwestern, northeastern and southeastern corners of the Gulf. Areas of divergence are plotted off the lower west coast of Florida and on the Campeche Banks. A number of minor features in the vertical circulation of less permanent nature and of more doubtful status are also revealed.

The horizontal distribution of vertical water movements may be defined from such information as temperature sections, from topographical charts of isothermal surfaces, or from kinematic observations of horizontal water movements at the surface. Temperature data, however, are relatively incomplete except for limited areas where intensive studies have been carried out, whereas average monthly surface drift vectors are charted in detail for wide areas. In order to deduce vertical movement from drift vectors it is first of all necessary to plot the streamlines. This involves a subjective process which may lead to errors. The subsequent deduction of vertical movements from visual inspection of the streamlines also fails to give a numerical expression of the intensity of such movements. Attention has therefore been given to the possibility of using a simple mathematical method of directly computing numerical values of vertical movement from the charted values of surface drift, without the preliminary plotting of streamlines.

Technique

The method used may be derived from a consideration of the stream functions at the intersecting points of the grid of a rectangular coordinate system. Pritchard (1948) has, by numerical integration, computed such stream functions and has used them for the purpose of plotting streamlines. In order to correct for discrepancies between the values of stream functions when integrated along different paths, he found it necessary to use an elaborate method of averaging. He also

[1]Contribution No. 59 from The Marine Laboratory, University of Miami.

pointed out that the method is inapplicable to the sea surface in localities where considerable areas of divergence or convergence exist. For the present purpose, the discrepancies between stream functions at a point computed along different paths may be used for the measurement of vertical movement and the averaging process is therefore eliminated.

The drift vectors along each side of a rectangle OAPB may be resolved into their components, u and v, directed parallel to the x and y axes respectively. The stream function of P with respect to O along any line joining these points is therefore

$$\Psi = \int (-vdx+udy).$$

Let the value be Ψ when integrated along OAP, and Ψ' when integrated along OBP. The net volume of water entering a vertical column of depth z based upon OAPB is therefore

$$\int(\Psi-\Psi')\, dz.$$

Positive values of this will be a measure of the rate at which water leaves the column by vertically downward movement due to convergence, while negative values will represent the movement due to divergence. No allowance is made for the effects of varying density or of precipitation and evaporation.

If the sides of OAPB are made equal to unity, and if the drift vectors at the midpoints of each side are assumed to be average values for the length of each side, then

$$\Psi = u_1-v_2 \text{ and } \Psi' = u_2-v_1$$

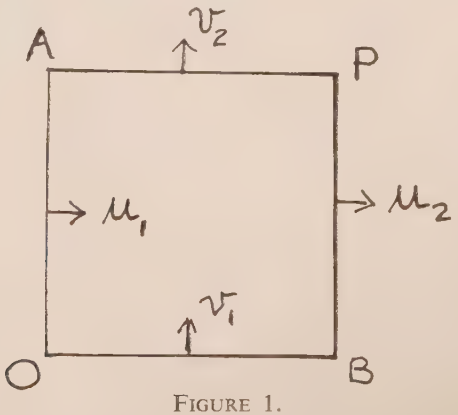

FIGURE 1.

using the notation of Figure 1. If the depth of the vertical column is

made unity, then the volume of water passing vertically into or out of a unit layer bounded at the surface by OAPB is $(u_1-v_2-u_2+v_1)$. Although this conclusion is here arrived at by a consideration of the stream function, it may be derived more directly from a consideration of surface flow across the sides of a unit rectangle as suggested by Sverdrup *et al.* (1942, page 425).

For practical purposes use is made of drift vectors given in each one degree rectangle of the Hydrographic Office surface current charts. Since the vector values are given for the midpoint of each rectangle, it would be necessary to average the vectors in pairs in order to obtain vector values for the midpoint of each side of the grid. This is obviated

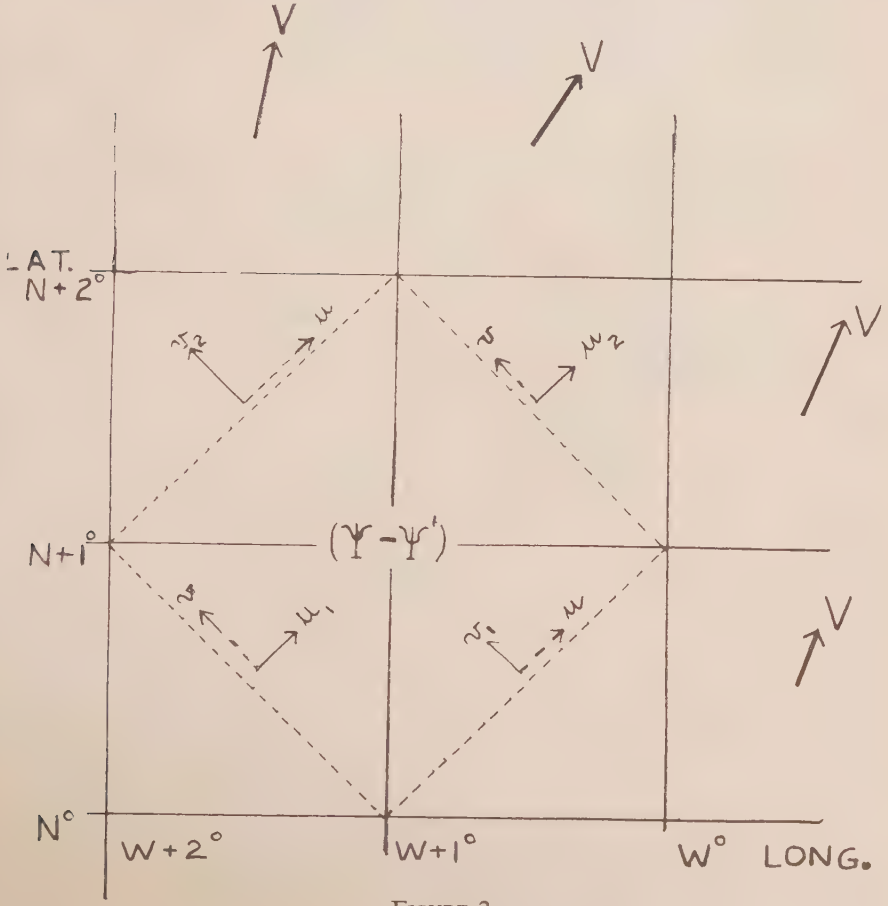

FIGURE 2.

by erecting a separate system of coordinates, the grid lines of which obliquely bisect the one degree rectangles (Figure 2). The drift vectors are resolved into two components, one at right angles and one parallel with each side of the new grid. The system is not a rectangular one since the one degree intervals of longitude are not equal.

Resolving the vectors into components at right angles to the sides of the new grid automatically compensates for the change from rectangular to non-rectangular coordinates. Each side of the new grid is a diagonal of the original reference grid. Therefore the sides are very nearly of equal length, and no correction is necessary for latitude as would be the case for the original quadrangle.

The resulting values of $(u_1-v_2-u_2+v_1)$ are plotted at the points of the mercator grid and joined by suitable isolines. Increasing positive values indicate increasing intensity of convergence, whereas negative values indicate divergence.

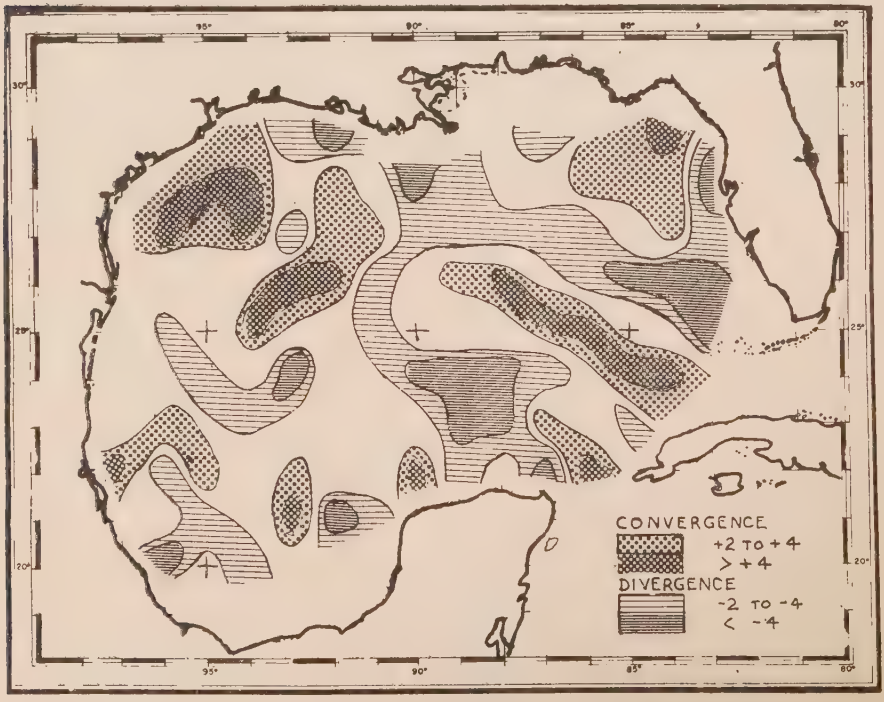

FIGURE 3. Indications of relative convergence and divergence during January to March.

FIGURE 4. Indications of relative convergence and divergence during April to June.

Application

Application of the method to waters of the Gulf of Mexico is based upon the average monthly drift vectors of the Hydrographic Office series of Current Charts for Central American Waters (H.O. Misc. 10,690-1 to 10,690-12). For convenience in reproduction the results are averaged for three-monthly periods, beginning with January (Figures 3, 4, 5, 6).

The values used in the figures are based upon convenient units. The drift velocities of the charts, in miles per 24 hours, are used in computing values of u and v. The vertical movement is therefore expressed in terms of the net residual surface movement directed into the area of each parallelogram of the grid in miles per day per unit length of grid. The area is twice that of the one degree rectangles of the mercator grid.

The charted results show that certain features are consistently pres-

ent at all seasons. The strong convergence in the northwestern part of the Gulf of Mexico, described in an early paper by Sweitzer (1898) and referred to by more recent authors, is well marked. The equally strong elongated line of convergence extending from the Florida Straits in a direction roughly west northwest is also well known. These two areas appear to be partially joined across the middle of the Gulf of Mexico by smaller areas of sinking water, which are particularly evident during November to January.

The area of convergence in the angle of the Florida coast at the northeastern corner of the Gulf of Mexico is small but appears throughout the year, except during summer months for which the drift data are insufficient to determine the condition in this area.

The principal area of divergence covers the greater part of the Campeche Bank, to the north of Yucatan. Although this is well developed during all months of the year it is least extensive during April,

FIGURE 5. Indications of relative convergence and divergence during July to September.

FIGURE 6. Indications of relative convergence and divergence during October to December.

when it is partly replaced immediately to the northwest of the Yucatan Channel by a small area of convergence which appears only during the first six months of the year.

A second permanent area of divergence is situated off the lower west coast of Florida. This is least extensive during May to July. During January and February it extends well across the Gulf towards New Orleans.

In addition to the more permanent features there are a number of smaller temporary ones. Because of the nature of the data upon which the computations are based it is doubtful to what extent these minor features should be taken into account. Nevertheless they appear consistently in the results. A convergence near the coast just south of Tampico is present during February to June. During July it moves further south and disappears for the remainder of the year. A stronger and more extensive convergence exists during part of the year in the

southern part of the Gulf of Campeche. It extends along the coast during the early summer and as a narrow band northward as far as 22°N. latitude during the winter. The current data are insufficient to follow the progress of the southerly portion of this during all months of the year.

The temporary convergences linking the northwestern and southeastern areas have already been mentioned. These extend across the middle of the western part of the Gulf and are only entirely absent during April to June.

Westward of the Mississippi Delta in longitude 92° to 93°W. an area of divergence appears during the greater part of the year. It is weakest in late summer. Immediately to the east of it a small convergence appears during June and August. The lack of sufficient current data for other months makes it difficult to follow the course of this during the remainder of the year. Immediately south of the Delta in 89° to 90°W. longitude a divergent condition exists. This is most pronounced during the winter months, when it appears to link up with the Yucatan and Florida divergences across the center of the Gulf.

A large area of divergence occurs to the north of the Gulf of Campeche. This is of very variable extent. During the early summer months it is almost absent, whereas during the winter it is partly connected with the Yucatan divergence.

The permanent features described by this method are not inconsistent with the evidence given by the topography of the 10°C. surface figured by Dietrich (1939). His chart shows depressions of this surface at places corresponding roughly to the permanent northeast, northwest and southeast convergences described above, to depths of over 500, 400, and 600 meters below the surface respectively. A fourth depression, at about 23°N. and longitude 94°W. does not correspond to any feature of the present results, however. The 10°C. surface is closest to the sea surface at positions coinciding with the Florida divergence and the Yucatan divergence, where it is less than 300 meters from the surface. In all other areas the isotherm lies at a depth of between 300 and 400 meters.

The stronger and more permanent vertical movements plotted by the method here described are therefore partly substantiated by temperature observations. It is not certain, however, to what extent the minor features may be relied upon. Intensive studies being carried out elsewhere may bring further information to bear upon this.

The method used does not include effects of evaporation and precipitation. Where the difference between these is relatively important it must be taken into consideration. In the area examined here, however, it is believed to be a minor factor. Similarly, although no allowance is made for variation in density, the effect of this is believed to be small in relation to that of the water currents. The values computed apply only to surface layers within which the horizontal velocity components remain fairly constant with depth. It is probable, however, that the major currents extend to relatively great depths so that the computed values in most cases represent vertical movements of considerable extent. Comparison with the temperature distribution tends to confirm this belief.

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MARINE BORING AND FOULING IN RELATION TO VELOCITY OF WATER CURRENTS[1]

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ABSTRACT

Experiments were conducted in order to determine the effects of current velocity upon the intensity of attack of species of *Teredo* and *Limnoria*. Observations upon *Balanus, Chthamalus* and *Schizoporella* species were also made. A sea-water pump was used to provide continuously increasing water velocities up to 2.2 knots in a tapered wooden box. The apparent limiting velocity for entrance of the borer *Teredo pedicellata* lay between 1.4 and 1.8 knots. The burrowing of *Limnoria* was prevented by currents of between 1.5 and 1.9 knots. Attachment of *Balanus amphitrite* was prevented at 2 knots, *B. improvisus* at 1.8 knots, *B. eburneus* at 0.8 knots, *Chthamalus fragilis* at 1 knot and *Schizoporella* and *Crassostrea* sp. at 1.4 knots. The bulk of shipworm attack occurred in the horizontal panels forming the bottom of the box. *Limnoria* was more evenly distributed. Barnacles and bryozoa were more numerous in the upper parts of the panels, possibly due to heavy silting on the lower panels. Maximum growth of *Balanus amphitrite, B. improvisus* and *Schizoporella sp.* was reached at about 0.2 knots, while that of *B. eburneus* was reached at 0.18 knots.

INTRODUCTION

The literature dealing with marine wood borers includes numerous studies on the relation of attack intensity to such physical factors as salinity, temperature, turbidity, dissolved gases and pH, with particular emphasis on the first two. Little attention, however, has been paid to the part played by water currents in limiting borer attack. As in the case of the barnacle, the brief period of transition from the planktonic larval form and metamorphosis to the sessile adult is the one most vulnerable to external conditions. For this reason the present investigations were carried out to determine the effect of currents upon initial penetration of borers.

Neither the larvae of shipworms nor the adult of *Limnoria*, in which dispersal is by the adult alone, are strong swimmers. The former relies upon a ciliated velum which is ineffective against any considerable current. When brought by chance currents into initial contact with a wooden structure, the foot is protruded and the young shipworm creeps over the surface until it finds a suitable place for entry. The

[1]Contribution No. 60 from The Marine Laboratory, University of Miami. These studies were aided by a contract between the Office of Naval Research and the University of Miami in cooperation with the U. S. Navy Bureau of Yards and Docks.

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velum is lost, and the young animal begins to burrow. Because of its irregular swimming habits and its small size, the dispersal of *Limnoria* is also dependent upon water currents to a considerable extent.

One of the few studies which expressly considers the effects of current velocity upon the attachment of sessile organisms is that of Smith (1946), who also summarizes the pertinent literature. His investigations, however, refer only to barnacles. The present investigations were primarily concerned with wood boring organisms although observations upon the barnacles and bryozoa encountered were also included.

Grateful acknowledgements are accorded to Mr. Anthony Pfeiffer who constructed the apparatus and to various members of the Marine Laboratory staff for their assistance in carrying out the experiments.

Methods

The apparatus consisted of a four-sided wooden tube of square cross-section and eight feet in length. The sides diminished in width gradually from one end to the other. In the first experiment the internal width varied from eight inches at the open end to two inches at the other end. In the second experiment the sides tapered from seven and one-half inches to one and one-half inches. The small end was attached by suction hose to the input end of a one and one-half inch, one horse-power electric water pump. The wooden tube was rigidly suspended in a horizontal position from the stationary M. V. *Physalia* in such a manner that it was continuously supported at a depth of 18 inches below the surface at all stages of the tide. The open end was covered by a galvanized screen of three-eighths inch mesh. Discharge of the pump was directed to the opposite side of the vessel. The apparent rates of flow, neglecting the effects of turbulence, ranged from about 0.1 to 2.2 knots.

The wood used in the construction of the tube was knot-free, soft yellow pine, one-half inch thick, and milled smooth on all surfaces. Rubber stripping was used to seal the tube at the seams, and the entire outer surface was painted with a commercial anti-fouling paint which successfully prevented entry of any borers through the outside.

The apparatus was exposed continuously for 28 days at two different times (April 9-May 8, 1949 and June 1-29, 1949) at the east end of the MacArthur Causeway, Miami Beach, Florida. Proximity to Government Cut provided sea water of normal salinity on the incoming tide, while the outgoing tide brought water of slightly lower salinity

from the northern part of Biscayne Bay.

For the purpose of counting the organisms each panel or side of the tube was divided into eight one-foot sections. The numbers of each type of boring or fouling organisms in each section were recorded and reduced to the quantity per unit area. The count of teredid borings was made under a low power dissecting microscope.

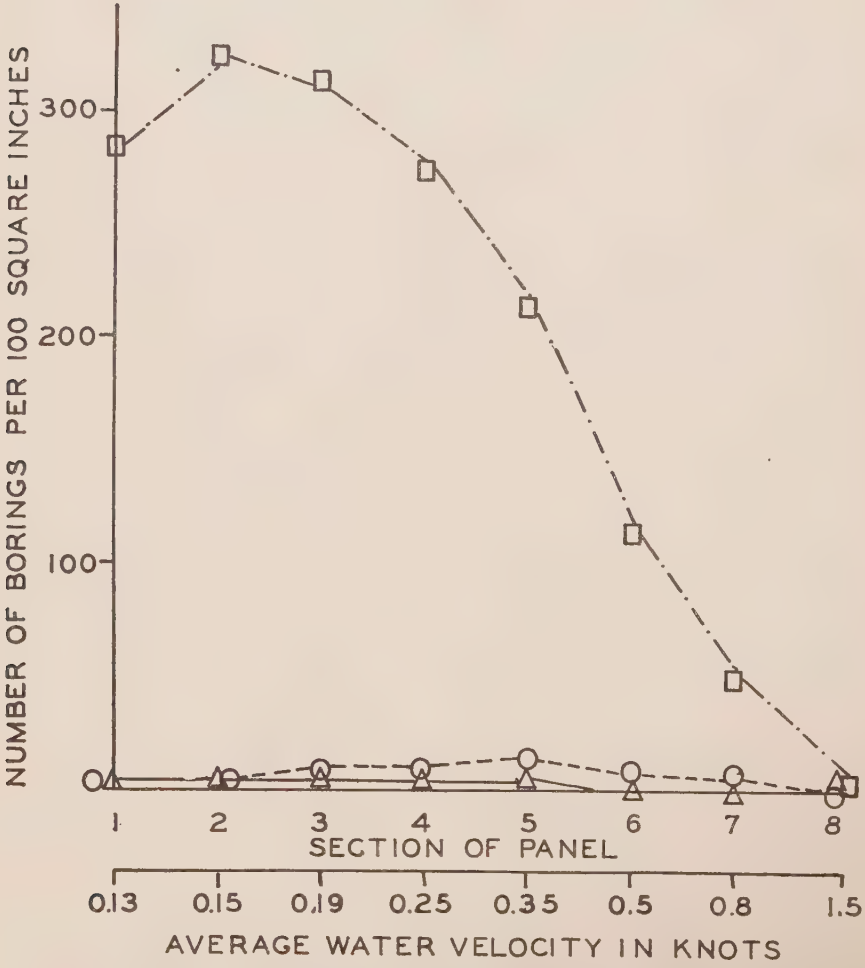

FIGURE 1. Intensity of boring by teredids in relation to water velocity and orientation of wooden surfaces. First experiment. Square conventions, lower horizontal panel; triangle, upper horizontal panel; circle, vertical panel.

Results

Results of the first experiment are shown in Figures 1 and 2. The second series of observations is given in tabular form in Table I. Observations upon fouling organisms are given in Figures 3 and 4 and in Tables II, III and IV.

Shipworms. With the exception of one individual each of *Bankia caribbea* Clench and Turner and *Martesia striata* (Linné), all identifiable molluscs were *Teredo* (*Lyrodus*) *pedicellata* Quatrefages, the dominant wood borer during this time of the year. Many of the borings observed were merely shallow depressions which were empty or contained a post-larval form too young to be identified. Every evidence of shipworm attack was counted, whether the organism remained or not. There is no reason to believe that, once the larva has begun to bore, it is capable of leaving the initial opening to begin another.

Ninety-two per cent of the teredids in the first experiment and 81 per cent in the second experiment were found in the horizontal bottom panel. Less than two per cent were in the top panel of the first experiment, and less than one per cent in the top panel of the second. Teredids of the vertical panels were predominant in their lower portions (Figure 1).

Except for the low count of all organisms within the first foot adjacent to the open end, there was generally a decrease in both borers and fouling organisms from the area of lower velocity to that of higher velocity. The lower count within the first foot, particularly noticeable in the second experiment (Table I), was apparently due to turbulent

TABLE I

Intensity of Borer Attack In Relation to Velocity of Water Currents
June 1-27, 1949

Expressed as number of borings per 100 square inches

Distance in feet from large end	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
Average velocity in knots	0.15	0.18	0.2	0.3	0.4	0.6	1.1	2.2
Shipworms,								
Top panel	1	0	0	2	0	3	4	4
Vertical panels	3	20	22	41	23	15	10	8
Bottom panel	54	226	241	308	247	145	43	0
Limnoria,								
Top panel	9	90	88	48	88	26	20	4
Vertical panels	17	113	78	80	80	45	47	6
Bottom panel	16	61	76	71	78	13	10	4

flow caused by the protective screen, which was sometimes partially blocked by debris. The first six inches adjacent to the screen in the second period of experiment bore a very small number of organisms, the second six inches accounting for nearly all of the animals recorded in the first foot. No teredids were present within the first six inches of any of the top or vertical panels of either experiment. In the first experiment there were 172 teredids per 100 square inches in the first six inches of the bottom panel, but in the second there were only 13 per 100 square inches.

In the first experiment the apparent maximum velocity at which any shipworms were found was 1.4 knots, at a point 3.7 inches from the small end. In the second, the furthest teredid was found 10.3 inches from the small end, where the velocity was calculated to be 1.8 knots. It is interesting to note that the latter was less than 1 mm. from the corner of the box, where the velocity of the current may have been considerably less than that at other parts of the sides.

Limnoria. Limnoria lignorum (Rathke), the gribble, is the most common wood boring crustacean in the Miami area. Although it is probably present, *Chelura* has not yet been recorded, and none of the local species of *Sphaeroma* have been found responsible for the initial destruction of wood. The distribution of *Limnoria* is entirely by adult forms, and all development takes place within the brood pouch of the female. They are erratic swimmers (Hill and Kofoid, 1927), and their transference by means of driftwood or currents or by wave action from structures damaged by their attack, is probably haphazard. An essential difference between the habits of teredids and gribbles is that the gribble may leave its burrow and begin another some distance away in search of the softer spring wood. The claws of the legs hold the animal firmly so that it may resist dislodgement by a stream of water much stronger than that to which it would be subject in its natural habitat or in an experiment such as this (Hill and Kofoid).

The majority of *Limnoria* burrows within the experimental tube were located at the edges of the panels which are probably the regions of lowest velocity in the tube's cross section. There was no consistent difference between numbers entering the top and bottom panels. In the first experiment the vertical panels sustained a significantly lower attack than the top and bottom panels (Figure 2). This was not so at the higher velocities of the second experiment. The majority of bur-

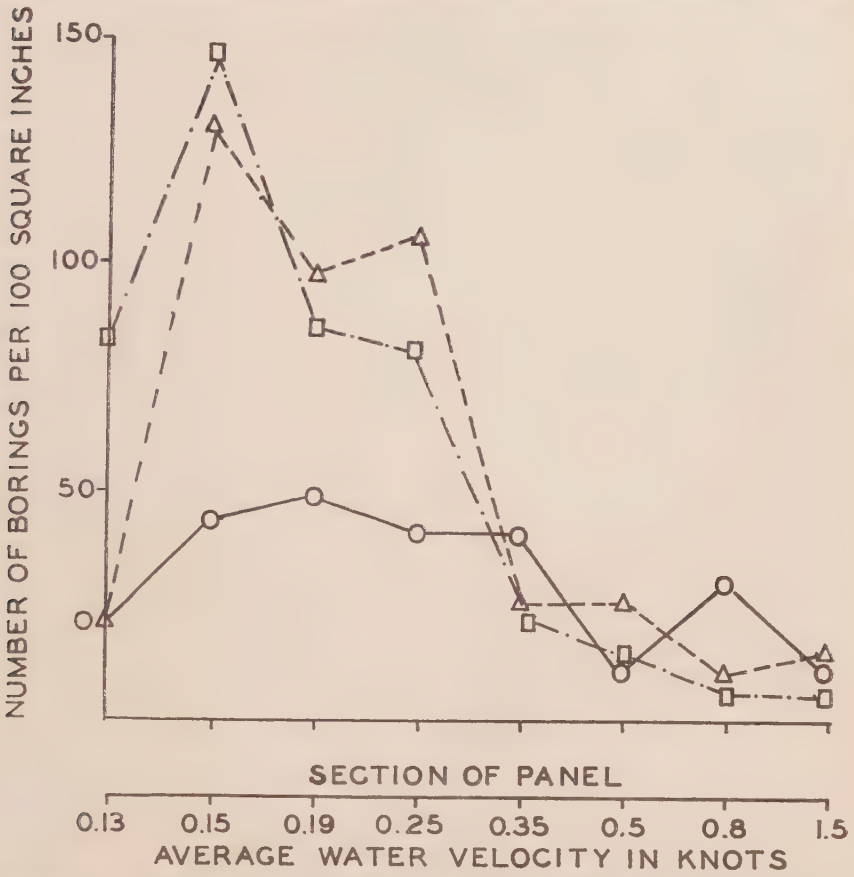

FIGURE 2. Intensity of boring by *Limnoria* in relation to water velocity and orientation of wooden surfaces. First experiment. Square conventions, lower horizontal panel; triangle, upper horizontal panel; circle, vertical panel.

rows on the vertical panels in both experiments were found at or near the top edge of the panel (Table I).

In the first experiment the greatest velocity permitting a complete burrow was found to be 1.48 knots, although a shallow pit, indicating an incipient burrow, was found at 1.55 knots. In the second experiment the limiting velocity for a complete burrow was 1.88 knots, with 2.83 knots for a shallow pit.

Fouling Organisms. No quantitative observations were made on fouling in the first experiment, but counts and measurements were made on

TABLE II
INTENSITY OF FOULING IN RELATION TO VELOCITY OF WATER CURRENTS
June 1-29, 1949
Expressed in number of organisms per 100 square inches

Distance in feet from large end	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	
Average velocity in knots	0.15	0.18	0.2	0.3	0.4	0.6	1.1	2.2	Avg.
B. amphitrite,									
Top panel	...	308	242	169	96	84	103	20	128
Side panels	...	256	177	169	138	101	57	16	114
Bottom panel	...	171	69	48	45	45	30	4	52
B. improvisus,									
Top panel	...	44	32	14	23	29	23	8	22
Side panels	...	66	42	31	28	30	23	4	28
Bottom panel	...	41	23	13	13	45	17	0	17
B. eburneus,									
Top panel	...	13	15	0	0	0	0	0	3.5
Side panels	...	16	17	23	4	4	0	0	8.0
Bottom panel	...	30	8	5	0	0	0	0	5.0
Chthamalus fragilis,									
Top panel	...	7	5	2	0	3	3	0	2.5
Side panels	...	5	2	1	0	0	0	0	1.0
Bottom panel	...	1	0	0	0	0	0	0	0.1
Schizoporella unicornis,									
Top panel	...	253	258	246	142	37	27	0	120
Side panels	...	340	312	252	182	59	0	0	143
Bottom panel	...	57	24	0	9	0	3	0	12

barnacles and encrusting bryozoa after the second exposure, with additional notes on the size of *Crassostrea virginica* and *Anomia simplex.* General observation showed interesting differences between the two experiments. Encrusting colonial tunicates (mainly *Didemnum candidum*) were among the most important organisms in the first period of exposure, while no measurable colonies of this were found in the second period. In the latter their position was filled by an abundant unidentified hydroid of dense low growth. *Balanus improvisus* Darwin was the dominant species of barnacles, with *B. amphitrite niveus* Darwin next in abundance in the first experiment; the situation was reversed in the second run.

Due to the previously mentioned abnormal distribution of all organisms in the first foot adjacent to the opening, no count was made of the fouling organisms in this part of the tube.

Within the smaller portion of the tube used in the second experiment there was an interesting area of moderate growth extending from

TABLE III

GROWTH RATE OF FOULING ORGANISMS IN RELATION TO VELOCITY OF WATER CURRENTS

Expressed in millimeters as greatest dimension of largest individual observed.*

Distance from large end in feet	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
Average water velocity in knots	0.15	0.18	0.2	0.3	0.4	0.6	1.1	2.2
B. amphitrite	. .	11.0	11.5	12.5	13.0	12.5	10.5	3.0
B. improvisus	. .	12.5	12.0	12.5	11.5	9.5	4.0	3.0
B. eburneus	. .	11.0	12.7	11.5	11.0	10.0	. .	. .
Chthamalus fragilis	. .	5.0	4.0	6.0	. .	5.0	4.5	. .
Schizoporella	. .	11.0	13.0	13.0	11.0	6.0	1.0	. .
Crassostrea	. .	10.5	6.0	8.0	11.0	3.0	0.5	. .
Anomia	. .	.75	. .	. .	. .	. .	. .	. .

*During 4 week period, June, 1949

about 20 inches from the outlet end to within about nine inches of it. Approximately two inches of nearly bare surface separated this area from the heavy growth in the remainder of the tube, producing in effect, an island of fouling organisms. An unbroken growth of hydroids about half as dense and half as tall as that in the larger portion established the extent of the irregularly shaped area. Among the hydroid colonies were a few small individuals of *Balanus improvisus, B. amphitrite, Schizoporella* and *Crassostrea* in addition to *Limnoria* and a few shipworms. The area may be explained on the basis of eddies which may have allowed the attachment of the hydroids. These, in turn, may have provided a more suitable substrate for the other animals.

Barnacles. Only a very few barnacles were found directed posteriorly to the direction of the flow, and these were entirely within the larger three-eighths of the tube. Other than this negative one, the barnacles exhibited no definite evidence of orientation to the direction of the current. The axes of some were at right angles to the current, while the axes of many more formed every angle to the current between 0° and 180°. This is completely at variance with the findings of Moore (1935), who described a definite orientation to currents in other barnacle species studied at the Isle of Man.

Balanus amphitrite was represented by a single individual at a point nine inches from the smaller end of the tube where the apparent velocity was 2.0 knots. *B. improvisus* attached up to an apparent velocity of 1.8 knots, *B. eburneus* up to 0.8 knots, and *Chthamalus fragilis*

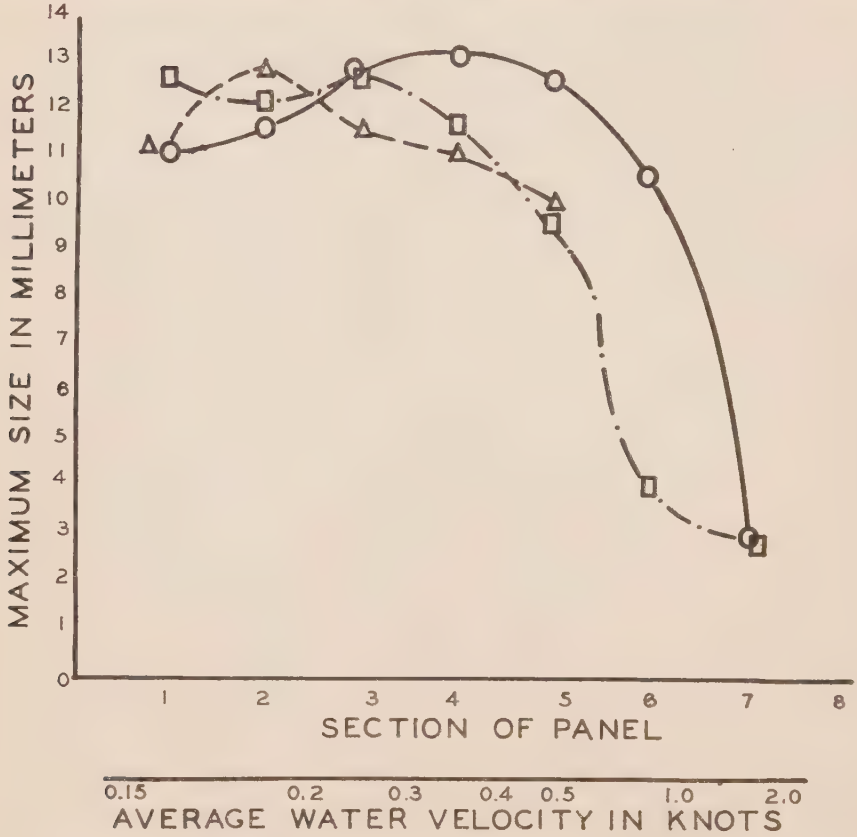

FIGURE 3. Growth of barnacles in relation to water velocity. Circular conventions, *B. amphitrite;* triangle, *B. eburneus;* square, *B. improvisus.*

up to approximately 1 knot. In all cases except *B. eburneus* the number of attachments upon the lower panel was considerably lower than elsewhere. This panel was usually coated with a layer of silt. *B. improvisus* and *B. eburneus* attached in somewhat greater numbers upon the vertical panels, but *Chthamalus fragilis* and *B. amphitrite* showed a slightly greater tendency to settle upon the upper panel.

The rate of growth of barnacles following attachment is given in Figure 3. The maximum growth rate of *B. amphitrite* took place at an apparent water velocity of 0.4 knots. The optimum velocity for *B. improvisus* was about 0.2 knots, for *B. eburneus* 0.18 knots, and for *Chthamalus* about 0.3 knots.

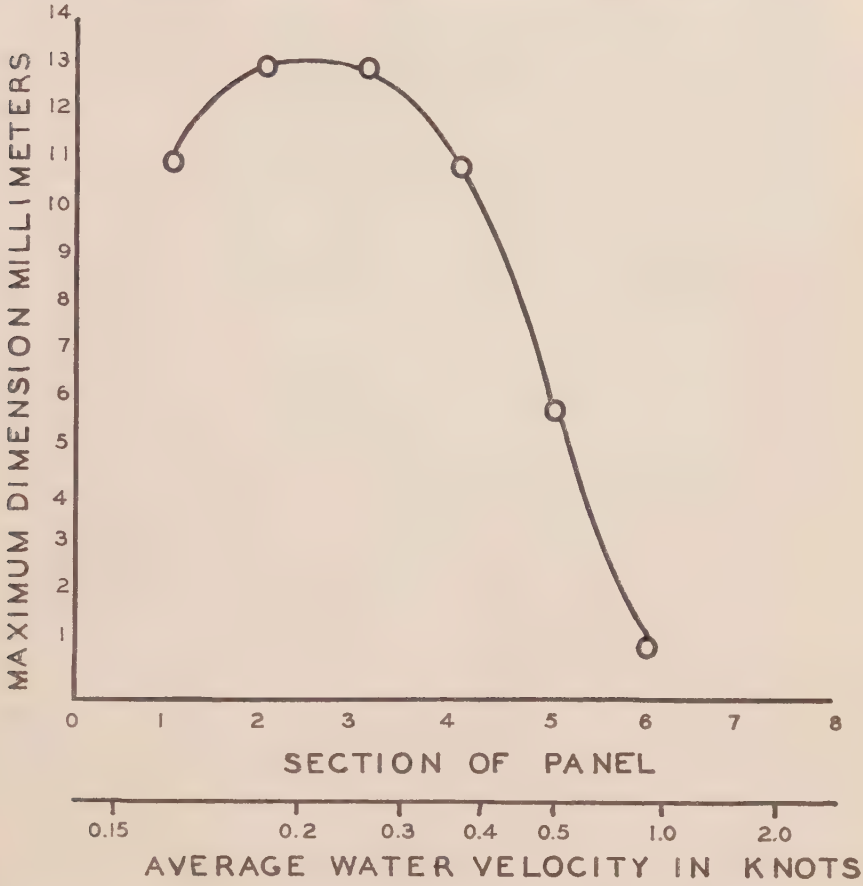

FIGURE 4. Growth of *Schizoporella* colonies in relation to water currents.

Other Fouling Organisms. The encrusting bryozoa found in both runs of the experiment were almost entirely *Schizoporella unicornis* (Johnson) with very few colonies of a species of *Microporella*. These organisms exhibited a strong tendency towards attachment on the upper and side walls. The vertical side accumulated 12 times and the top panel 10 times the concentration on the bottom panel. The difference between the populations of the bottom and of the other panels here is markedly greater than that for the barnacles as a group. This may be due to the fact that the bryozoans are less successful in coping with the problem of silt due to their less erect growth.

A small colony of three zooecia (1 mm.) was found 14.8 inches from the excurrent end of the tube. The average velocity of the current there was 1.4 knots, and no bryozoans were found beyond this limit. Greatest growth rate was found at an apparent current of 0.2 knots (Figure 4).

The individual *Crassostrea* found nearest the small end of the apparatus was 0.5 mm. in diameter. The velocity of flow at that point was 1.36 knots.

The unidentified hydroid attached at velocities up to 2 knots and extended stolons beyond this point.

Discussion

The results show clearly that borer attacks are greatly reduced by an increased rate of flow in the surrounding water. This is readily explained as a purely mechanical effect of the water movement. The limiting velocities, between 1.4 and 1.9 knots, are markedly higher than the velocities which have been shown in this and previous investigations (Smith, 1946) to prevent attachment of barnacles. Since *Limnoria* is provided with appendages whereby it may secure itself to the wooden surface, this is to be expected. Teredids apparently are able to retain their grip on the surface by means of a secretion of the foot. Repeated observations at Miami indicate that immediately contact is made between the foot and the substrate, it becomes harder to dislodge them by means of water currents. Barnacles, on the other hand, have a poor hold on the wooden surface until sufficient time has elapsed for the extrusion of the antennal cement, whereby preliminary attachment is effected. Prior to this the antennal suction cups provide a very insecure hold (Doochin, 1951).

Unpublished field observations in the Miami area have shown that, particularly in water of less than full ocean salinity, intensity of teredid attack increases from the surface downwards. In the present experiments teredid attack was considerably greater upon the lower wall of the wooden box than elsewhere. Previous reports have shown that the larvae have a slight negative buoyancy and tend to sink passively downwards whenever ciliary activity ceases. (Isham, *et al.*, 1951). This tendency has been considered as a possible cause of the observed distribution of borings over the walls of the box. If this were so, one would expect to find an equal vertical distribution at the entrance to the box with a continuously increasing proportion of borings in the

lower walls as the distance from the entrance increased. This would follow from the increasing number of larvae which sank as the water traversed the box. Since, in fact, such a change in distribution with distance from the entrance was clearly absent (Figure 1), it is necessary to seek for an explanation elsewhere.

A possible explanation lies in the occurrence of silt on the lower sides and bottom of the box. Whereas silt of this nature tends to prevent attachment of barnacles, it may increase the ability of shipworms to enter the wood, since they are known to be able to burrow through it quickly and so obtain immediate protection from the mechanical effects of current. In this connection reference may also be made to frequent reports from field observers to the effect that borer attacks are greater near the mudline.

The comparatively equal distribution of *Limnoria* between upper and lower sides of the box is in accordance with field observations on the distribution of *Limnoria* with depth in the Miami area.

The prevention of boring by strong water currents indicates that, except in crevices or in places where stream pockets occur, borer attack is not likely to take place in wooden hulls while vessels are under way, or during periods of strong tidal flow while at anchor. On the other hand, once the borer has entered it is protected by its burrow from any subsequent flow of water. It must be concluded, therefore, that, because of the intermittent nature of tidal flow, the mooring of a vessel in a tideway offers little or no protection against borer attack.

The experimental results apparently show higher limiting velocities for the attachment of barnacles than do previous experiments (Smith, 1946). This is not altogether surprising, since the complicated nature of stream flow and turbulence in experiments of this kind does not permit of an accurate estimation of the water velocities actually present at the surface where attachment takes place.

The fouling organisms were predominant upon the upper and vertical walls of the box. According to Grave (1930), and Pomerat and Reiner (1942), the cyprids of many barnacles and larvae of bryozoa exhibit a strong negative geotaxis. Cyprids are also known to swim with their ventral side uppermost so they may attach less readily to the upper side of horizontal surfaces such as the lower panel of the experimental box. It is possible, however, that the observed distribution was simply due to the presence of heavy silt which ob-

structed attachment to the lower side of the box. The silting does not affect teredids or *Limnoria,* which are able to burrow through it.

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A PRELIMINARY REVIEW OF THE WESTERN NORTH ATLANTIC FISHES OF THE FAMILY SCOMBRIDAE[1]

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ABSTRACT

This paper brings up to date the taxonomy of the western North Atlantic mackerels and tunas. In addition to a key to the genera and species, a complete synonymy, a diagnosis and pertinent comments, are given under each species.

INTRODUCTION

THE LITERATURE on scombrid fishes is extensive and widely scattered throughout various journals, mostly in the form of small papers dealing with single or very few species. Despite Fraser-Brunner's recent world-wide revision of the group (1950), there is still confusion as to the identity of several important species, and owing to this, the current keys to western Atlantic scombrids are not workable. In addition, many obvious and important taxonomic characters have been overlooked and ontogenetic variation has been almost entirely ignored.

The mackerel-like fishes form a natural taxonomic entity well defined from other groups on the basis of many important features. This group has been variously split into separate families (Acanthocybiidae, Cybiidae, Scombridae, Katsuwonidae, Thunnidae) or considered as a single natural family (Scombridae). The latter view has been adopted here and the scombroid fishes of the families Gempylidae and Trichiuridae are not considered in the present work. The following abbreviated diagnosis characterizes the family Scombridae.

> Body typically fusiform. Head subconic, pointed. Caudal peduncle very slender at root of caudal fin. Premaxillaries not protractile. Anterior dorsal fin with weak spines, entirely depressible into a groove. Second dorsal fin similar to the anal. Last rays of second dorsal and anal fins detached and separate, forming a row of several finlets extending to the base of the caudal fin.

The present paper is based mainly on the material in the United states National Museum, the Museum of Comparative Zoology and Stanford University Natural History Museum. I am grateful to the officers of these institutions for their kindness in allowing me to study

[1]Contribution No. 61 from The Marine Laboratory, University of Miami.

the material under their care. In addition, the material in the reference collection of the University of Miami Marine Laboratory has been used in connection with the present work and many freshly captured specimens belonging to several species have been studied at game fishing centers in the Bahamas, Florida and Cuba.

As implied by the title, the present work is not intended as a thorough revision of the group since much study remains to be done before scombrid fishes can be considered as well understood. It is hoped, however, that the key, diagnoses and comments offered in this paper will serve as a means of identification and help solve the existing confusion involving some of the species.

Illustrations of the species of western north Atlantic scombrids in the form of drawings or photographs are available in many current works, and rather than reproduce or duplicate them here, references to the most accurate figures are given after the diagnosis of each species. The taxonomic characters used in the key and diagnoses are self-explanatory.

Key to the Genera and Species of Western North Atlantic Scombridae

1a.—Dorsal fins far apart: Distance between base of last spine of first dorsal fin and origin of second dorsal fin much longer than snout. Dorsal spines 9 to 12. Longest soft dorsal and anal rays about equal to or somewhat shorter than diameter of eye.

2a.—Scales covering entire body, not forming a corselet on pectoral region. Caudal peduncle without a median keel on each side. No dermal flap between pelvic fins. Posterior part of maxillary entirely concealed by preorbital. Dorsal finlets 5; anal finlets 5. (*Scomber*).

3a.—Dorsal spines 11 or 12. Seventh dorsal spine more than half as long as 3rd dorsal spine. Air bladder absent.

1. *Scomber scombrus,* p. 213.

3b.—Dorsal spines 9 or 10. Seventh dorsal spine about half as long as 3rd dorsal spine. Air bladder present.

2. *Scomber colias,* p. 214.

2b.—Scales present only on anterior part of body, along lateral line and along the back to origin of second dorsal fin; those on pectoral region enlarged and forming a corselet. Caudal peduncle with a median keel on each side. A conspicuous, lanceolate dermal flap between pelvic fins. Posterior part of maxillary partially concealed by preorbital. Dorsal finlets 8 or 9; anal finlets 7. (*Auxis*).

3. *Auxis thazard,* p. 215.

1b.—Dorsal fins close together: Distance between base of last spine of first dorsal fin and origin of second dorsal fin shorter than snout. Dorsal spines 13 to 26. Longest soft dorsal and anal rays longer than diameter of eye.

4a.—Dorsal spines 13 to 22. Gill rakers present. Snout much shorter than rest of head. Posterior part of maxillary not entirely concealed by preorbital. Center of eye nearer tip of snout than posterior margin of opercle. Origin of second dorsal fin nearer origin of first dorsal fin than last dorsal finlet.

5a.—Gill rakers 36 to 40 on lower limb of first arch. Distance between origin of second dorsal fin and last dorsal finlet less than distance between tip of snout and origin of first dorsal fin. About 3 to 5 dark, longitudinal stripes along lower sides of body, converging towards caudal peduncle. (*Katsuwonus*).

4. *Katsuwonus pelamis,* p. 216.

5b.—Gill rakers 7 to 29 on lower limb of first arch. Distance between origin of second dorsal fin and last dorsal finlet greater than distance between tip of snout and origin of first dorsal fin. No dark, longitudinal stripes along lower sides of body.

6a.—Scales present only on anterior part of body, along anterior portion of lateral line and along the back to second dorsal fin; scales on pectoral region enlarged and forming a corselet. A few, irregularly scattered, dark blotches about as large as pupil, on sides of body below pectoral fin. (*Euthynnus*).

5. *Euthynnus alletteratus,* p. 216.

6b.—Scales covering entire body, sometimes enlarged on pectoral region and forming a corselet. No irregularly scattered, dark blotches on sides of body below pectoral fin.

7a.—Dorsal spines 13 to 15, the first spine about as long as or longer than the second and third, the following spines rather abruptly decreasing in length; outline of first dorsal fin concave. Gill rakers 14 to 28 on lower limb of first arch. Maxillary not reaching beyond vertical from center of eye, its posterior part partially concealed by preorbital. Pectoral fin reaching to or beyond vertical from 10th dorsal spine. (*Thunnus*).

8a.—Pectoral fin not reaching to origin of anal fin. Head about equal to or shorter than distance between tip of pectoral fin and caudal keel.

9a.—Gill rakers 25 to 28 on lower limb of first arch. Pectoral fin not reaching beyond vertical from 12th dorsal spine.

6. *Thunnus thynnus,* p. 217.

9b.—Gill rakers 15 to 22 on lower limb of first arch. Pectoral fin reaching beyond vertical from 12th dorsal spine, usually to, or beyond origin of second dorsal fin.

10a.—Gill rakers 15 to 19 on lower limb of first arch. Dorsal finlets 7 to 9, usually 8;

anal finlets 7 or 8. Maxillary 2.4 or 2.5 in head. Second dorsal and anal fins not notably increasing in length with age; never reaching beyond 2nd or 3rd finlet when depressed.

7. *Thunnus atlanticus*, p. 219.

10b.—Gill rakers 20 to 22 on lower limb of first arch. Dorsal finlets 8 to 11, usually 9 or 10; anal finlets 8 to 10. Maxillary 2.6 or 2.7 in head. Second dorsal and anal fins increasing in length with age, greatly produced and reaching to or beyond 7th finlet when depressed in larger, adult specimens.

8. *Thunnus argentivittatus*, p. 221.

8b.—Pectoral fin reaching beyond origin of anal fin. Head longer than distance between tip of pectoral fin and caudal keel.

9. *Thunnus alalunga*, p. 222.

7b.—Dorsal spines 15 to 22, the first spine shorter than the second, the following spines gradually decreasing in length; outline of first dorsal fin straight or slightly convex. Gill rakers 7 to 14 on lower limb of first arch. Maxillary reaching beyond vertical from center of eye, its posterior part not concealed by preorbital. Pectoral fin not reaching to vertical from 10th dorsal spine.

11a.—Maxillary reaching beyond vertical from posterior margin of orbit. Scales absent on opercle and top of head. Caudal keels without scales. Corselet developed. Teeth conical, somewhat compressed, slightly curved inward, absent on vomer. Origin of anal fin under, or somewhat behind end of second dorsal fin base. Dorsal spines 18 to 22. Numerous dark stripes on back, running obliquely downward and forward. (*Sarda*).

12a.—Dorsal spines 20 to 22. Gill rakers 12 to 14 on lower limb of first arch. Head 3.5 to 3.7 in length to end of caudal keel.

10. *Sarda sarda*, p. 223.

12b.—Dorsal spines 18. Gill rakers 7 to 9 on lower limb of first arch. Head 3.2 to 3.5 in length to end of caudal keel.

11. *Sarda orientalis*, p. 223.

11b.—Maxillary not reaching beyond vertical from posterior margin of orbit. Scales present on opercle

and top of head to interorbital. Caudal keels well covered with scales. Corselet not developed. Teeth knife-shaped much compressed, not curved inward, present on vomer. Origin of anal fin in advance of end of second dorsal fin base. Dorsal spines 15 to 18. No oblique, dark stripes on back. (*Scomberomorus*).

13a.—Gill rakers 7 to 9 on lower limb of first arch. Dorsal spines 15 or 16. Lateral line abruptly curving downward below second dorsal fin. First dorsal fin not black anteriorly (except in young).

12. *Scomberomorus cavalla,* p. 224.

13b.—Gill rakers 10 to 13 on lower limb of first arch. Dorsal spines 17 or 18. Lateral line not abruptly curving downward below second dorsal fin. First dorsal fin black anteriorly.

14a.—Gill rakers 12 or 13 on lower limb of first arch. Maxillary not quite reaching to vertical from posterior margin of orbit. Pectoral fin scaled. Sides of body with spots and one or two longitudinal stripes.

13.*Scomberomorus regalis,* p. 225.

14b.—Gill rakers 10 or 11 on lower limb of first arch. Maxillary reaching to vertical from posterior margin of orbit. Pectoral fin not scaled. Sides of body with spots but without longitudinal stripes.

14. *Scomberomorus maculatus,* p. 225.

4b.—Dorsal spines 24 to 26. Gill rakers absent. Snout about as long as rest of head. Posterior part of maxillary entirely concealed by preorbital. Center of eye nearer posterior margin of opercle than tip of snout. Origin of second dorsal fin nearer last dorsal finlet than origin of first dorsal fin. (*Acanthocybium*).

15. *Acanthocybium solandri,* p. 226.

1. *Scomber scombrus* Linnaeus
Common mackerel

Scomber scombrus Linnaeus, 1758: 297 (original description after *Scomber pinnulis V* of Artedi; Atlantic). Jordan and Evermann, 1896: 865 (characters in key;description; synonymy); 1900, pl. 133, fig. 363. Hildebrand and Schroeder, 1928: 201 (description; Chesapeake Bay), fig. 114. Jordan, Evermann and Clark, 1930: 257 (listed; common names; distribution; synonmy). Breder, 1948: 123 (figure; comments). Fraser-Brunner, 1950: 153 (characters in key), 155 (synonymy; distribution), fig. 22.

Scomber vernalis Mitchill, 1815: 423 (original description; Sandy Hook, N.J.).

Diagnosis: Dorsal spines 11 or 12. Dorsal finlets 5. Anal finlets 5. Gill rakers about 30 on lower limb of first arch. Posterior part of maxillary entirely concealed by preorbital. Scales covering entire body. Corselet absent. Pectoral fin reaching to vertical from 5th or 6th dorsal spine. *Illustrations:* Jordan and Evermann, 1900, pl. 133, fig. 363. Hildebrand and Schroeder, 1928: 201, fig. 114. Breder, 1948: 123.

The well known common mackerel is seasonal in occurrence and appears off the American Atlantic coast north of Cape Hatteras between the end of March and the middle of April, remaining until November. This northern species is entirely absent from the Gulf and Caribbean regions.

The common mackerel reaches a length of 22 inches (260 mm.) and a weight of 4 pounds, and may be readily distinguished from its relative, the chub mackerel (*Scomber colias*) by the number of dorsal spines and the absence of an air bladder.

For a comprehensive account of the biology of *Scomber scombrus,* see Bigelow and Welsh (1925: 188-208).

2. *Scomber colias* Gmelin

Chub mackerel; Tinker mackerel; Easter mackerel; Thimble-eyed mackerel; Spanish mackerel of England.

Lacerto Cetti, 1777: 190 (Sardinia).
Scomber colias Gmelin, 1788: 1329 (original description based on *Lacerto* of Cetti). Jordan and Evermann, 1896: 865 (characters in key), 886 (description). Meek and Hildebrand, 1923: 308 (description).
Scomber lacertus Walbaum, 1792: 209 (original description based on *Lacerto* of Cetti).
Scomber pneumatophorus De La Roche, 1809: 315, 334 (original description; Balearic Islands).
Scomber macrophthalmus Rafinesque, 1810: 15 (original description; Palermo).
Scomber grex Mitchill, 1815: 422 (original description; New York).
Scomber maculatus Couch, 1832: 22 (original description; England).
Scomber undulatus Swainson, 1839: 409 (original description; Sicily).
Scomber gracilis Swainson, 1839: 410 (original description; Sicily).
Scomber dekayi Storer, 1867: 130 (original description; Massachusetts coast).
Scomber species dubia Poey, 1868: 360 (description; Cuba).
Pneumatophorus grex, Jordan, Evermann and Clark, 1930: 258 (listed; synonymy; distribution).
Pneumatophorus colias, Breder, 1948: 124 (figure; comments).

Diagnosis: Dorsal spines 9 or 10. Dorsal finlets 5; anal finlets 5. Gill rakers 25 to 30 on lower limb of first arch. Posterior part of maxillary entirely concealed by preorbital. Scales covering entire body. Corselet absent. Pectoral fin reaching to vertical from 4th, 5th or 6th

dorsal spine. *Illustrations:* Jordan and Evermann, 1900, pl. 133, fig. 364. Breder, 1948; 124.

This widely distributed species has been described under various names through ignorance of previous descriptions or misinterpretation of poor, early descriptions. The western Atlantic representatives (*grex*) are not separable from those of the eastern Atlantic (*colias*). Fraser-Brunner (1950: 153, 154) interpreted *Scomber colias* only as subspecificially distinct from *S. japonicus* but I prefer to retain the Atlantic form as a distinct species until more thorough comparative studies are effected.

This species had never been reported south of Virginia and its occurrence in the West Indian region is now confirmed by a specimen 220 mm. in standard length from Garden Key, Florida (U.S.N.M. No. 8033). Specimens 110 mm. in length recorded by Poey (1868: 360) from Cuba as *Scomber species dubia* also belong to this species.

3. *Auxis thazard* (Lacépede)

Frigate mackerel; Skipjack; Albacora

Scomber thazard Lacépède, 1802: 9 (original description; New Guinea).
Scomber rochei Risso, 1810: 165 (original description; Nice).
Scomber bisus Rafinesque, 1810: 45 (original description; Palermo).
Thynnus rocheanus Risso, 1826: 417 (original description; Nice).
Auxis vulgaris Cuvier and Valenciennes, 1831: 139 (original description; Mediterranean).
Auxis tapeinosoma Bleeker, 1854: 408 (original description; Japan).
Auxis thynnoides Bleeker, 1855: 301 (original description; Ternate).
Auxis rochei, Günther, 1860: 369 (description). Jordan, Evermann and Clark, 1930: 259 (listed).
Auxis thazard, Jordan and Evermann, 1896: 867 (description; synonymy). Evermann and Marsh, 1900: 122 (description; synonymy; Puerto Rico), fig. 27. Meek and Hildebrand, 1923: 313 (description; synonymy). Beebe and Tee-Van, 1928: 99 (description; figure; Haiti). Nichols, 1929: 229 (figure; comments). Breder, 1948: 124 (figure; comments). Rivas, 1949: 10 (listed; common name; distribution). Fraser-Brunner, 1950: 140 (characters in key), 152 (synonymy; comments), 153, fig. 20.

Diagnosis: Dorsal spines 9 to 11. Dorsal finlets 8 or 9; anal finlets 7. Gill rakers 29 to 33 on lower limb of first arch. Posterior part of maxillary partially concealed by preorbital. Scales present only on anterior part of body, along lateral line, and along the back to second dorsal fin. Corselet present. Pectoral fin reaching to vertical from 7th or 8th dorsal spine. *Illustrations:* Jordan and Evermann, 1900, pl. 133, fig. 365. Breder, 1948: 124.

This cosmopolitan species is very erratic in its occurrence off the western Atlantic coasts. It may not be seen for years and will occa-

sionally appear in large numbers. Great quantities were sold at Fulton Market in New York City during the summer of 1949. It is also occasionally seen in West Indian markets.

Although *Auxis thazard* is a very well marked species, it is little known by commercial and game fishermen of the western north At-Atlantic.

This species is said to reach a weight of 10 pounds but individuals weighing about one to five pounds are usually taken. A two pound individual is about 400 mm. (15.5 inches) long to end of caudal keel.

4. *Katsuwonus pelamis* (Linnaeus)

Oceanic bonito; Arctic bonito; Oceanic skipjack; Striped tuna; Victor fish; Bonito; Albacora

Scomber pelamis Linnaeus, 1758: 297 (original description; "In pelago inter tropico").
Scomber pelamides Lacépède, 1802: 14 (description after Linnaeus).
Thynnus pelamys, Cuvier and Valenciennes, 1831: 113 (description).
Gymnosarda pelamis, Jordan and Evermann, 1896: 868 (description; synonymy). Meek and Hildebrand, 1923: 310 (description; synonymy). Breder, 1948: 124 (figure; comments).
Katsuwonus pelamis, Jordan, Evermann and Clark, 1930: 258 (listed; distribution). Godsil and Byers, 1944: 26-45 (anatomy; description; comments; Pacific Ocean), fig. 4. Rivas, 1949: 10 (listed; common names).
Euthynnus (*Katsuwonus*) *pelamis,* Fraser-Brunner, 1950: 150 (characters in key), 152 (synonymy; comments), fig. 19.

Diagnosis: Dorsal spines 15 or 16. Dorsal finlets 7 or 8, usually 8; anal finlets 6 to 8, usually 7. Gill rakers 36 to 40 on lower limb of first arch. Posterior part of maxillary not entirely concealed by preorbital. Scales present only on anterior part of body, along lateral line and along the back to second dorsal fin. Corselet present. Pectoral fin reaching to vertical from 8th or 9th dorsal spine. *Illustrations:* Godsil and Byers, 1944: 26, fig. 4. Breder, 1948: 124.

This species is rather common throughout the tropical northwestern Atlantic and may be readily recognized in the field by the longitudinal, dark stripes along the lower sides of the body. It reaches a length of 2 feet and a weight of 20 pounds. The flesh is excellent and of commercial importance in the West Indian region.

For a detailed treatment of this cosmopolitan species see Godsil and Byers (1944: 27-45).

5. *Euthynnus alletteratus* (Rafinesque)

Little tuna; Little tunny; False albacore; Bonito; Albacore; Vaca

Scomber alletteratus Rafinesque, 1810: 46 (original description; Palermo).

Thynnus leachianus Risso, 1826: 414 (original description; Nice).
Scomber quadripunctatus Geoffroy St. Hilaire, 1827, pl. 24 fig. 3 (Egypt).
Thynnus thunnina Cuvier and Valenciennes, 1831: 104 (original description; Mediterranean).
Thynnus brasiliensis Cuvier and Valenciennes, 1831: 110 (original description; Brazil).
Thynnus brevipinnis Cuvier and Valenciennes, 1831: 112 (original description; Mediterranean).
Gymnosarda alletterata, Jordan and Evermann, 1896: 869 (description; synonymy). Meek and Hildebrand, 1923: 311 (description; synonymy). Beebe and TeeVan, 1928: 99 (description; figure; Haiti). Breder, 1948: 125 figure; comments).
Euthynnus alletteratus, Jordan, Evermann and Clark, 1930: 258 (listed; synonymy). Longley and Hildebrand, 1941: 72 (description; Tortugas). Rivas, 1949: 10 (listed; common names). Fraser-Brunner, 1950: 150 (characters in key), 151, fig. 18, 152 (synonymy; comments).

Diagnosis: Dorsal spines 14 to 16. Dorsal finlets 8 or 9; anal finlets 6 or 7. Gill rakers 25 to 29 on lower limb of first arch. Posterior part of maxillary not entirely concealed by preorbital. Scales present only on anterior part of body, along lateral line and along the back to second dorsal fin. Corselet present. Pectoral fin reaching to vertical from 10th, 11th or 12th dorsal spine. *Illustrations:* Jordan and Evermann, 1900; pl. 134, fig. 366. Breder, 1948: 125.

Many individuals of this species have been examined. They range in size from 300 to 1000 mm. in length. The number of gill rakers varies from 25 to 29 on the lower limb of the first arch, not 29 or 30 as stated by Fraser-Brunner (1950: 150).

This species is well known to commercial and game fishermen and may be considered as the most common tuna in the western North Atlantic. It may be readily recognized in the field by the presence of several, irregularly scattered, dark blotches on the sides of the body below the pectoral fin. The flesh is good and of commercial importance throughout the West Indies. Although *E. alletteratus* may reach a weight of fifteen pounds or more, individuals weighing over ten pounds are not often taken. The average weight is about three pounds and a specimen weighing 3.75 pounds measures about 500 mm. (19.75 inches) in length to end of caudal keel.

6. *Thunnus thynnus* (Linnaeus)

Bluefin tuna; Great tuna; Tuna; Tunny; Horse mackerel; Great albacore; Thon; Atún

Scomber thynnus Linnaeus, 1758: 297 (original description based on *"Scomber pinnulis 8 seu 9,"* of Artedi).
Thynnus mediterraneus Risso, 1826: 414 (original description; Nice).

Thynnus vulgaris Cuvier and Valenciennes, 1831: 58 (original description; European seas), pl. 210.

Thynnus brachypterus Cuvier and Valenciennes, 1831: 98 (original description; Mediterranean), pl. 211.

? *Thynnus coretta* Cuvier and Valenciennes, 1831: 102 (original description; Caribbean Sea).

Thynnus secundo-dorsalis Storer, 1867: 143 (original description; Cape Ann and Provincetown). Breder, 1948: 125 (figure; comments). Jordan, Evermann and Clark, 1930: 260 (listed). Rivas, 1949: 10 (listed; common names).

Thunnus thynnus, Jordan and Evermann, 1896: 870 (description; synonymy in part). Meek and Hildebrand, 1923: 314 (description; synonymy in part). Godsil and Byers, 1944: 88-102 (anatomy; description; comments; comparisons; California; Guadalupe Island, Mexico), fig. 48. Rivas, 1949: 10 (listed; common names). Godsil and Holmberg, 1950: 5-55 (comparison of populations: New England, Australia, California). Fraser-Brunner, 1950: 142 (characters in key), 143 (synonymy in part; comments), fig. 4.

Diagnosis: Dorsal spines 14 or 15. Dorsal finlets 9; anal finlets 8. Gill rakers 25 to 28 on lower limb of first arch. Posterior part of maxillary not entirely concealed by preorbital. Scales covering entire body. Corselet present. Pectoral fin reaching to vertical from 11th or 12th dorsal spine. *Illustrations:* Godsil and Byers, 1944: 88, fig. 48. Breder, 1948: 125.

As indicated in the synonymy, the Atlantic populations of *Thunnus thynnus* have been interpreted as representing distinct species by various authors. Godsil and Holmberg (1950) have demonstrated that the American Atlantic and American Pacific populations may be considered as separate species, but published studies and my own investigations show that the eastern and western Atlantic populations belong to the same species.

Fraser-Brunner (1950: 142) describes *Thunnus thynnus* in his key as having 21 to 26 gill rakers on the lower limb of the first arch. He does not state whether or not this range of variation includes the western Atlantic population which according to Godsil and Holmberg (1950: 11) and my own studies, shows a range of variation of 25 to 28 gill rakers on the lower limb of the first arch. Further study may show that the eastern and western Atlantic populations are separable at the subspecies level on the basis of gill raker count and minor internal characters.

During late May and early June, large bluefin tuna pass along the edge of the Bahama Banks off Orange Cay, Riding Rocks, Cat Cay, Bimini and Grand Bahama Island, moving in a northerly direction. The same fish appear later off the New England coast during July through October. While passing through the strait between Florida

and the Bahamas, the fish keep to the eastern side of the Gulf Stream and very few specimens have been captured or seen along the mainland of Florida or the keys. There is reason to believe that another run passes at the same time along the outer (eastern) edge of the Bahama Banks off Eleuthera, Abaco and Walker Cay, and joins the Florida Strait run at the northwestern end of Little Bahama Bank off Manzanilla Shoals. As pointed out by Poey (1868: 361), large individuals measuring up to 9 feet in length are captured in deep water off Havana, Cuba during late May. This indicates that the Florida Strait migration may come in from the Caribbean through the Yucatan Channel and pass along the north coast of western Cuba. Personal communications from various well informed commercial and game fishermen indicate that there may be another run moving into the Strait of Florida during May-June, along the Old Bahama Channel off the north coast of central and eastern Cuba. The species has also been reported (*in litt.*) by Louise Victoria Smith of the Institute of Jamaica from the waters of that island. She informs me that there is a regular annual run of bluefin tuna off the northeastern coast of Jamaica during February through April, from California Banks up to Port Antonio or beyond.

Individuals of this species are said to reach a length of 15 feet and a weight of 1800 pounds, but specimens weighing over 1000 pounds are seldom captured. The individuals captured off Bimini and Cat Cay during May-June average 500 pounds. The smallest specimens known from the western Atlantic measure 280 and 420 mm. from tip of snout to end of caudal keel. They are in the reference collection of the University of Miami Marine Laboratory and were collected off Miami, Florida.

For a detailed treatment of this species, see Godsil and Byers (1944: 88-102) and Godsil and Holmberg (1950).

7. *Thunnus atlanticus* (Lesson)

Blackfin tuna; Albacore; Albacora

Thynnus atlanticus Lesson, 1830: 165 (original description; Trinidad island, South Atlantic).

Thynnus balteatus Cuvier and Valenciennes, 1831: 136 (original description after Lesson; tropical Atlantic).

Parathunnus obesus (not of Lowe). Beebe and Tee-Van, 1928: 100 (description; comments; figure; Haiti).

Parathunnus rosengarteni Fowler, 1934: 354, 356 (original description; Florida), figs. 3-5.

Parathunnus ambiguus Mowbray, 1935: (no pagination; type not designated; Bermuda).

Parathunnus atlanticus, Beebe and Tee-Van, 1936: 178-184 (synonymy; description; comparisons; Bermuda; West Indies), pls. 1-2, figs. 1-4. Rivas, 1949: 10 (listed; common name).

Diagnosis: Dorsal spines 13 or 14. Dorsal finlets 7 to 9; anal finlets 7 or 8. Gill rakers 15 to 19 on lower limb of first arch. Posterior part of maxillary not entirely concealed by preorbital. Scales covering entire body. Corselet present. Pectoral fin reaching to vertical from 12th dorsal spine, to origin of second dorsal fin or somewhat beyond, but not to origin of anal fin. *Illustrations:* Beebe and Tee-Van, 1936, pls. 1-2, figs. 1-4.

This well marked species has nearly always been confused with its close relative *Germo=Thunnus alalunga* (see p. 222) and does not appear in faunal works on western Atlantic fishes except as a synonym of the latter species. In his recent revision of scombrid fishes, Fraser-Brunner (1950: 143) erroneously includes *Thunnus atlanticus* in the synonymy of *T. alalunga* without comment but considers *T. obesus* (Lowe) as a separate species "shorter and stouter than *T. alalunga*, but otherwise not distinguishable with certainty except by dissection." *Thunnus atlanticus* is closer to *T. obesus* than to *T. alaunga* and may be distinguished from both of these species by the number of gill rakers on the lower limb of the first arch: 15 to 19 in *T. atlanticus*, 18 to 25 in *T. obesus* (according to Fraser-Brunner) and 19 to 22 in *T. alalunga*. In *T. atlanticus* the pectoral fin never reaches to a vertical from the origin of the anal fin, whereas in *T. alalunga* the pectoral fin is much longer and always reaches well beyond a vertical from the origin of the anal fin. *Thunnus obesus* seems to be intermediate between *T. atlanticus* and *T. alalunga* in this respect. The correct identity of *T. atlanticus* was definitely established by Beebe and Tee-Van (1936) on the basis of specimens from Bermuda and the West Indies and a thorough study of the literature. My own studies are in complete accord with Beebe and Tee-Van's work which was apparently overlooked by Fraser-Brunner (1950).

The blackfin tuna is well known to commercial and game fishermen throughout the West Indian Area where it is considered as a rather common scombrid being taken along with *Euthynnus alletteratus* and *Katsuwonus pelamis* although in smaller quantities. The three species apparently school together. According to Mowbray (*ambiguus*), *Thunnus atlanticus* grows to a weight of 60 pounds. It is most frequently taken at an average size of about 500 mm. (19.75 inches) corresponding to a weight of about 7 pounds.

8. *Thunnus argentivittatus* (Cuvier and Valenciennes)

Yellowfin tuna; Allison tuna; Albacore; Albacora; Atún

?Scomber albacares Bonnaterre, 1788: 140 (original description after a drawing by Sloane, 1707; Madeira).
?Scomber sloanei Cuvier and Valenciennes, 1831, 107 (original description after a drawing by Sloane, 1707; Madeira).
Thynnus argentivittatus Cuvier and Valenciennes, 1831: 97 (original description; Atlantic and Pacific Oceans).
Thynnus albacora Lowe, 1839: 77 (original description; Madeira).
Orcynus species dubia Poey, 1868: 361 (description; comparisons; Cuba).
Orcynus subulatus Poey, 1875: 71 (original description; comparisons; Cuba).
Thunnus allisoni Mowbray, 1920: 78 (original description; Florida), figs. 9-10.
Neothunnus argentivittatus, Beebe and Tee-Van, 1936: 184-192 (synonymy; description; comparisons; comments; Bermuda; West Indies), pls. 3-7, figs. 5-13. Rivas, 1949: 10 (listed; common names).
Neothunnus allisoni, Breder, 1948: 125 (figure; comments).
Thunnus (Neothunnus) albacora, Fraser-Brunner, 1950: 142 (characters in key), 144 (synonymy; comments), 145, fig. 7.

Diagnosis: Dorsal spines 14. Dorsal finlets 8 to 11; anal finlets 8 to 10. Gill rakers 20 to 22 on lower limb of first arch. Posterior part of maxillary not entirely concealed by preorbital. Scales covering entire body. Corselet indistinct. Pectoral fin reaching to vertical from origin of second dorsal fin or somewhat beyond, but not to vertical from origin of anal fin. *Illustrations:* Beebe and Tee-Van, 1936, pls. 3-7, figs. 5-13. Fraser-Bruner, 1950: 145, fig. 7.

Although Sloane's description and figure (1707) may refer to this species, there are certain discrepancies relating to the length of the pectoral fin. Consequently, the names *Scomber albacares* and *S. sloanei* are questionable, and I agree with Beebe and Tee-Van (1936: 186) in that the earliest valid name available for the Atlantic yellowfin tuna is *argentivittatus* (Cuvier and Valenciennes, 1831: 97). Frased-Brunner (1950: 144) lists the latter name as a synonym of this species in correct chronological sequence, but uses *albacora* (Lowe, 1839) as its valid name without comment. The name *Orcynus subulatus* Poey (1875: 71) clearly refers to the Atlantic yellowfin tuna, but Fraser-Brunner (1950: 143) erroneously synonymized it with the bluefin tuna (*Thunnus thynnus*). The author agrees with Beebe and Tee-Van (1936: 184) and Fraser-Brunner (1950: 144, 145) in that *Thunnus allisoni* Mowbray (1920: 78) merely represents a growth stage rather than a valid species.

Like *Thunnus atlanticus,* its near relative, *T. argentivittatus* has often been confused with *T. alalunga* and synonymized with the latter species. Both *T. argentivittatus* and *T. alalunga* have the same number

of gill rakers on the lower limb of the first arch (19 or 20 to 22) but *argentivittatus* has a shorter pectoral fin (see key and diagnosis) and the second dorsal and anal fins generally increase in length with age. A detailed comparison of specimens with high and with low second dorsal and anal fin lobes is given by Beebe and Tee-Van (1936: 187-190). The young of *T. argentivittatus* and *T. atlanticus* are distinguishable with certainty only by gill raker count.

The yellowfin tuna is a very important game and commercial fish and well known throughout the western north Atlantic. It reaches a length of over 1500 mm. (59 inches) and a weight of more than 150 pounds. A detailed treatment of this species is given by Beebe and Tee-Van, 1936.

9. *Thunnus alalunga* (Gmelin)

Albacore; Albacora; Long-finned albacore; Germon

Ala-lunga Cetti, 1777: 191 (Sardinia).

Scomber alatunga Gmelin, 1788: 1330 (original description based on Cetti; misprint for "alalunga"; Sardinia).

Scomber germo Lacépède, 1802: 598 (original description; South Pacific Ocean: 17° S. lat. and 103° W. long.).

Germo alalunga, Jordan and Evermann, 1896: 871 (common names; description; synonymy in part). Meek and Hildebrand, 1923: 316 (synonymy in part; description). Jordan, Evermann and Clark, 1930: 260 (listed; synonymy in part). Breder, 1948: 126 (figure; comments). Rivas, 1949: 10 listed; common names).

Thunnus (*T.*) *alalunga,* Fraser-Brunner, 1950: 142 (characters in key), 143 (synonymy in part; distribution).

Diagnosis: Dorsal spines 13 or 14. Dorsal finlets 7 or 8; anal finlets 7 or 8. Gill rakers 19 to 22 on lower limb of first arch. Posterior part of maxillary not entirely concealed by preorbital. Scales covering entire body. Corselet present. Pectoral fin reaching well beyond vertical from origin of anal fin. *Illustrations:* Jordan and Evermann, 1900, pl. 134, fig. 367. Godsil and Byers, 1944: 70, fig. 36.

As already discussed under *Thunnus atlanticus* and *T. argentivittatus,* this species has nearly always been accepted as valid, but various other near relatives have been confused and synonymized with it. *Thunnus alalunga* may be distinguished from all the other species of western north Atlantic scombrids by the long pectoral fin which reaches well beyond a vertical from the origin of the anal fin.

There are no authentic records of *Thunnus alalunga* from the western North Atlantic and expressions such as "rarely seen on the Atlantic Coast of America," or "Atlantic: north to Massachusetts, but rare

north of Florida," are not supported by actual specimens and almost certainly are based on the ever confused *T. atlanticus*. The species is well known from the Pacific coast of America, the eastern Atlantic and the Mediterranean and it may well occur in the western Atlantic.

A detailed anatomical treatment of this species is given by Godsil and Byers (1944: 71-87) in their systematic study of the Pacific tunas.

10. *Sarda sarda* (Bloch)

Atlantic bonito; Common bonito; Bonito; Boston mackerel; Bloater

Scomber sarda Bloch, 1793: 35 (original description; Europe), pl. 334.
Scomber mediterraneus Bloch and Schneider, 1801: 23 (original description after Brünnich, 1768; Marseilles).
Scomber pelamitus Rafinesque, 1810: 44 (original description; Palermo), pl. 2.
Sarda sarda, Jordan and Evermann, 1896: 872-873 (description; synonymy). Meek and Hildebrand, 1923: 319-320 (synonymy; description). Hildebrand and Schroeder, 1928: 206-207 (synonymy; description; comments; Chesapeake Bay), fig. 117. Jordan, Evermann and Clark, 1930: 259 (listed; synonymy). Breder, 1948: 126 (figure; comments). Rivas, 1949: 10 (listed; common names; distribution). Fraser-Brunner, 1950: 146 (characters in key), 147 (synonymy; distribution), fig. 11.

Diagnosis: Dorsal spines 20 to 22. Dorsal finlets 8 or 9; anal finlets 6 or 7. Gill rakers 12 to 14 on lower limb of first arch. Posterior part of maxillary not concealed by preorbital. Scales covering entire body. Corselet present. Pectoral fin reaching to vertical from 10th, 11th, or 12th dorsal spine. *Illustrations:* Hildebrand and Schroeder, 1928: 206, fig. 117. Breder, 1948: 126. Fraser-Bruner, 1950: 147, fig. 11.

This species represents the true "bonito," common along the Atlantic coast of the United States but not known from the Gulf and Caribbean areas and southward. It is an important commercial fish said to reach a weight of 12 pounds but the usual size is only about 2-4 pounds. For further information in regard to this species, see Hildebrand and Schroeder, 1928: 206-207, fig. 117.

11. *Sarda orientalis* (Temminck and Schlegel)

Striped bonito; Bonito; California bonito; Skipjack

Pelamys orientalis Temminck and Schlegel, 1844: 99 (original description; Japan), pl. 52.
Sarda velox Meek and Hildebrand, 1923: 318 (characters in key), 320 (original description; Panama), pl. 24. Breder, 1932: 31 (Block Island); 1948: 126. (figure; comments; Block Island).
Sarda orientalis, Fraser-Brunner, 1950: 146 (characters in key), 147 (synonymy; comments; distribution), fig. 12.

Diagnosis: Dorsal pines 18. Dorsal finlets 7 or 8; anal finlets 7. Gill

rakers 7 to 9 on lower limb of first arch. Posterior part of maxillary not concealed by preorbital. Scales covering entire body. Corselet present. Pectoral fin reaching to vertical from 8th or 9th dorsal spine. *Illustrations:* Meek and Hildebrand, 1923, pl. 24. Breder, 1948: 126. Fraser-Brunner, 1950: 147, fig. 12.

The author has not seen individuals of this species from the western north Atlantic, but Breder (1932: 31) has reported it from Block Island, R.I. under the name of *Sarda velox* on the basis of a specimen ". . . about 560 mm. in standard length and although in the process of being dressed for the table was clearly identifiable." The existence of *Sarda orientalis* in the western north Atlantic, however, needs further confirmation. *Sarda velox*, described by Meek and Hildebrand (1923: 320) from the Pacific (Panama) is not specifically distinct from *S. orientalis*, as indicated by Fraser-Brunner (1950: 147).

12. *Scomberomorus cavalla* (Cuvier)

Kingfish; King mackerel; Cavalla; Serrucho; Sierra; Carite

Cybium cavalla Cuvier, 1829: 200 (original description after Guarapucu of Marcgrave; Brazil). Cuvier and Valenciennes, 1831: 187 (description; Brazil).

Cybium immaculatum Cuvier and Valenciennes, 1831: 191 (description; no locality).

Scomberomorus cavalla, Jordan and Evermann, 1896: 873 (characters in key), 875 (common names; description; synonymy). Evermann and Marsh, 1900: 123 characters in key), 124 (description; synonymy; Puerto Rico). Meek and Hildebrand, 1923: 321 (characters in key), 322 (synonymy; description). Nichols, 1929: 230 (distribution; diagnosis). Jordan, Evermann and Clark, 1930: 257 (listed; common names; disrtibution; synonymy). Longley and Hildebrand, 1941: 71 (comments; Tortugas, Florida). Breder, 1948: 127 (figure; comments). Rivas, 1949: 9 (listed; common names). Erdman, 1949: 301 (occurrence; characters in key). Fraser-Brunner, 1950: 158 (characters in key), 160 (synonymy; comments), 161, fig. 33.

Diagnosis: Dorsal spines 15 or 16. Dorsal finlets 8 or 9; anal finlets 9 or 10. Gill rakers 7 to 9 on lower limb of first arch. Posterior part of maxillary not concealed by preorbital. Scales covering entire body. Corselet not developed. Pectoral fin reaching to vertical from 8th or 9th dorsal spine. *Illustrations:* Breder, 1948: 127. Fraser-Brunner, 1950: 161, fig. 33.

This important commercial fish occurs throughout the tropical and subtropical western north Atlantic but it is most abundant around South Florida during the winter and may be readily distinguished in the field by the absence of black on the spinous dorsal fin anteriorly (except in young), the low gill raker count, and the lateral line ab-

ruptly decurved below the second dorsal fin. It reaches a weight of 100 pounds and over 5 feet in length, being the largest species of the genus *Scomberomorus*.

13. *Scomberomorus regalis* (Bloch)

Cero; Cero mackerel; Sierra; Serrucho; Pintada; Carite

Scomber regalis Bloch, 1793:38, pl. 333 (after a drawing by Plumier; Martinique).

Scomberomorus plumieri Lacépède, 1802: 292 (after Aubriet's copy of Plumier's drawing; Martinique).

Cybium acervum Cuvier and Valenciennes, 1831: 186 (original description; Cuba).

Scomberomorus regalis, Jordan and Evermann, 1896: 873 (characters in key), 875 (common names; description; synonymy); 1900, pl. 135, fig. 369. Evermann and Marsh, 1900: 123 (characters in key), 124 (description; synonymy; Puerto Rico), fig. 28. Meek and Hildebrand, 1923: 322 (characters in key), 323 (synonymy; description). Hildebrand and Schroeder, 1928: 203 (characters in key), 205 (synonymy; description; Chesapeake Bay), fig. 116. Beebe and Tee-Van, 1928: 97 (characters; figures; remarks; Haiti). Nichols, 1929: 230 (figure; distribution; diagnosis; remarks; Puerto Rico). Jordan, Evermann and Clark, 1930: 257 (listed; common names; distribution; synonymy). Longley and Hildebrand, 1941: 71 (comments; Tortugas, Florida). Breder, 1948: 127 (figure; comments). Rivas, 1949: 10 (listed; common names). Erdman, 1949: 301 (occurrence; characters in key). Fraser-Brunner, 1950: 157 (characters in key), 160 (synonymy; distribution), fig. 32.

Diagnosis: Dorsal spines 17 or 18. Dorsal finlets 8 or 9; anal finlets 8. Gill rakers 12 or 13 on lower limb of first arch. Posterior part of maxillary not concealed by preorbital. Scales covering entire body. Corselet not developed. Pectoral fin reaching to vertical from 8th or 9th dorsal spine. *Illustrations:* Jordan and Evermann, 1900, pl. 135, fig. 369. Evermann and Marsh, 1900: 124, fig. 28, Breder, 1948: 127.

This species occurs throughout the entire western north Atlantic being very abundant around Cuba where the fishermen call it "pintada." It is intermediate in size between *Scomberomorus cavalla* and *S. maculatus* and readily distinguished from both these species by the gill raker count, the coloration (see diagnosis and key), and the presence of scales on the pectoral fin. *Scomberomorus regalis* may reach a weight of 35 pounds, but it is usually taken at an average size of 2 to 5 pounds.

14. *Scomberomorus maculatus* (Mitchill)

Spanish mackerel; Sierra; Serrucho; Pintada

Scomber maculatus Mitchill, 1815: 426 (original description; New York).

Scomberomorus sierra Jordan and Starks, 1895: 428 (original description; Mazatlan).

Scomberomorus maculatus, Jordan and Evermann, 1896: 873 (characters in key), 874 (common names; description; synonymy); 1900, pl. 134, fig. 368. Meek and Hildebrand, 1923: 322 (characters in key), 324 (synonymy; description; Panama). Hildebrand and Schroeder, 1928: 203 (characters in key; synonymy; description; Chesapeake Bay). Beebe and Tee-Van, 1928: 97 (characters in key; figure; remarks; Haiti). Jordan, Evermann and Clark, 1930: 257 (listed; distribution; synonymy). Hildebrand and Cable, 1938: 508-518 (development and life history; Beaufort, North Carolina), figs. 2-10. Longley and Hildebrand, 1941: 71 (comments; Tortugas, Florida). Breder, 1948: 127 (figure; comments). Rivas, 1949: 10 (listed; common names). Erdman, 1949: 301 (occurrence in the West Indies; characters in key). Fraser-Brunner, 1950: 157 (characters in key), 159 (synonymy; distribution), fig. 29.

Diagnosis: Dorsal spines 17 or 18. Dorsal finlets 8 or 9; anal finlets 8 or 9. Gill rakers 10 or 11 on lower limb of first arch. Posterior part of maxillary not concealed by preorbital. Scales covering entire body. Corselet not developed. Pectoral fin reaching to vertical from 9th or 10th dorsal spine. *Illustrations:* Jordan and Evermann, 1900, pl. 134, fig. 368. Hildebrand and Schroeder, 1928: 203, fig. 115. Breder, 1948: 127. Fraser-Brunner, 1950: 159, fig. 29.

The occurrence of this species in the West Indies has been discussed by Erdman (1949: 301), who came to the tentative conclusion that *Scomberomorous maculatus* probably occurs only along the north coast of Cuba. He mentions that *S. maculatus* has been recorded from the West Indies and that the records "are open to doubt," but he does not specifically refer to anyone in particular. However, Beebe and Tee-Van (1928: 97) very definitely report it from Port-au-Prince Bay, Haiti, on the basis of many specimens preserved and observed in the field.

This species is very important commercially and occurs throughout the entire western north Atlantic. It reaches a weight of 10 pounds or more (average weight 2 pounds).

The early development of *Scomberomorous maculatus* has been worked out by Ryder (1882: 135-172) and by Hildebrand and Cable (1938: 508-517).

15. *Acanthocybium solandri* (Cuvier and Valenciennes)
Wahoo; Queenfish; Peto

Cybium solandri Cuvier and Valenciennes, 1831: 192 (original description after MS. of Solander; open sea, locality unknown).

Cybium sara Lay and Bennett, 1849: 63 (original description; Loo Choo), pl. 20, fig. 2.

Cybium petus Poey, 1860: 234 (original description; Havana). pl. 16, fig. 1.
Cybium verany Doderlein, 1872 (original description; Palermo).
Acanthocybium solandri, Jordan and Evermann, 1896: 876 (common names; description; synonymy). Meek and Hildebrand, 1923: 326 (synonymy; description). Jordan, Evermann and Clark, 1930: 256 (listed; common names; synonymy). Breder, 1948: 127 (figure; comments). Rivas, 1949: 9 (listed; common names; distribution). Fraser-Brunner, 1950: 161 (fig. 35), 162 (synonymy; distribution).

Diagnosis: Dorsal spines 24 to 26. Dorsal finlets 9; anal finlets 9. Gill rakers undeveloped. Posterior part of maxillary entirely concealed by preorbital. Scales covering entire body. Corselet indistinct. Pectoral fin reaching to vertical from 12th or 13th dorsal spine. *Illustrations:* Fraser-Brunner, 1950: 161, fig. 35.

This cosmopolitan species is a well known game fish throughout the Caribbean Area, especially along the north coast of western Cuba where it abounds during the winter. It seems to be a migratory fish occurring along the Gulf Stream, especially throughout the Straits of Florida.

The wahoo may reach a length of six feet and a weight of 100 pounds or more.

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FURTHER DESCRIPTION OF *OCTOPUS BURRYI* VOSS WITH A NOTE ON ITS DISTRIBUTION[1]

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ABSTRACT

The former knowledge of *Octopus burryi* is supplemented by the description of the male characteristics and the general anatomy of the species. The taxonomic characteristics are clarified by the addition of five new specimens from the Gulf of Mexico, bringing the total known number of individuals to six, and the geographical distribution of the species is discussed.

The original description of this species (Voss, 1950) was based upon a single immature female taken by Mr. L. A. Burry from 100 fathoms on the Pourtales Plateau off the Florida Keys. With only one specimen available no dissection was made so that until additional specimens came to hand our knowledge of this species was confined to the external morphology and a brief description of the female genital organs. The specimens described here were taken in the Gulf of Mexico by the U.S. Fish and Wildlife Service exploratory vessel "Oregon" during the past year under the direction of Mr. Stewart Springer. By arrangement with Mr. Springer and Mr. H. R. Bullis, Jr. the "Oregon" cephalopods have been sent to the author for identification and a detailed report on their collections is now in progress. When the five new specimens of *O. burryi* were received, it was deemed advisable, however, to make a full and detailed report on this interesting and at the present time rather rare octopod.

Octopus burryi Voss

Octopus burryi Voss, 1950, pp. 76-79, figs. 2 and 3.

MATERIAL

No. 1, male, in formalin, "Oregon" Sta. 82, 29° 21.7′ N, 88° 11′ W; 38 fathoms from 40 ft. shrimp trawl; August 9, 1950.

Nos. 2 and 3, males, in formalin, "Oregon" Sta. 237, 24° 46′ N, 82° 59′ W; 25 fathoms from 100 ft. Texas trawl; January 20, 1951; bottom temperature 68.4° F., surface temperature 68° F.

No. 4, male, in formalin, "Oregon" Sta. 440, 19° 48′ N, 91° 20′ W; 14 fathoms from 100 ft. flat trawl; August 25, 1951; bottom temperature 80.8° F., surface temperature 82.6° F.

No. 5, female, in formalin, "Oregon" Sta. 232, 25° 03.5′ N, 83° 08′ W; 30 fathoms from 40 ft. flat trawl; January 19, 1951; bottom temperature 60.4° F., surface temperature 68° F.

[1]Contribution No. 62 from The Marine Laboratory, University of Miami.

Three of the above specimens are sexually mature males containing spermatophores so that it is now possible to record the male characteristics and to supplement the taxonomic differences noted for this species in the original description. With the exception of the large female, No. 5, all of the specimens show what now must be considered the characteristic markings for this species, i.e., a uniform reddish brown color on the dorsal surface of the mantle, head, web and arms, tending to orange ventrally, and light yellow on the oral surface of the web and arms, with a *conspicuous* purplish brown band extending the full length of the arms on the dorsal (inner) side. In the large female, the ground color is a bluish gray on the mantle upon which are superimposed the large flattened papillae which are brown. On the web in the area below the head, there is a reddish purple reticulation which extends to the base of the arms. The purple bands on the arms are distinct. Only specimen No. 1 shows indications of the dark bar across the eye previously described, and in none of the specimens is there any indication of an ocellus-like spot as was erroneously described from the holotype. Upon re-examination of the type during the past summer at Washington, all indications of such an ocellus had disappeared and it now seems likely that the spot noticed was due to preservation.

The sculpture is quite distinctive in all of the specimens, consisting of numerous large, closely-set round to oval papillae which are strongly elevated above the general surface of the skin except in the large female in which the papillae appear like flattened oval plates, somewhat rugose, on the smooth surface of the mantle. This sculpture is very noticeable and affords a ready means of identification, in no way resembling the rugosity of *O. vulgaris* in certain states of preservation. All of the specimens bear a single, prominent cirrhus above and slightly posterior to each eye.

TABLE I

Octopus burryi Voss. Body Proportions of 2 Female and 4 Male Specimens

Specimens	Mantle Length (mm.)	Mantle Width Index	Head Width Index	No. Gill Lam.
Holotype	30.0	73.3	50.0	8
No. 1	39.0	84.7	64.0	10
No. 2	50.0	58.0	42.0	9
No. 3	54.0	67.7	53.8	9
No. 4	26.5	71.6	56.5	10
No. 5	65.0	67.6	46.2	10-11

The measurements and indices of body proportions for the six known specimens are given in Tables I and II.

The lower mantle-width index and head-width index noted in specimen No. 2 are probably due to distortion in preservation as the specimen was considerably compressed when received. The number of gill lamellae per demibranch is rather high, comparing well with the number recorded for *O. macropus* and *O. vulgaris,* but the difficulty in accurately determining the terminal elements in this species should be noted.

TABLE II

Octopus burryi Voss. Body Proportions of 2 Female and 4 Male Specimens (Cont.)

Specimen	Mantle Arm Index	Arm Width Index	Web Depth Index	Sucker Index Normal	Arm Formula
Holotype	35.2	16.6	24.7	10.0	4>3>2>1
No. 1	33.3	19.2	23.9	12.8	3>4>2>1
No. 2		16.0		9.0	
No. 3	39.0	18.5	34.8	13.0	
No. 4	47.5	15.0	37.5	9.4	4=3>2>1
No. 5	40.0	18.5	40.0	9.2	4=3>2>1

Unfortunately specimens Nos. 2 and 3 were considerably damaged in the large commercial nets employed, thus rendering it impossible to make a more accurate determination of the arm order. The web order apparently is quite variable, although sector A is always much shallower than any of the others, and either D or C is the deepest. There are no specially enlarged suckers on the three males.

The male characteristics are given in Table III. The ligula of Nos. 1 and 3 are shown in Figure 1. Specimen No. 2 has lost the hectocotylized arm. In general the calamus is stout, plainly grooved and connecting directly with the deep well-formed spermatophoral groove. The ligula is not deeply excavated and contains about 15 transverse grooves or laminae copulatoriae which are quite distinct.

TABLE III

Octopus burryi Voss. Male Characteristics of Specimens Nos. 1, 3 and 4

Specimen	Hectocotylized Arm (mm.)	Ligula (mm.)	Ligula Length Index	Calamus Length Index	Penis Length Index
No. 1	73.0	4.0	4.1	45.0	27.8
No. 3	122.0	5.0	5.5	35.0	23.0
No. 4	53.0	2.5	4.7	25.0	22.2

Specimen No. 1 was dissected for an examination of the male

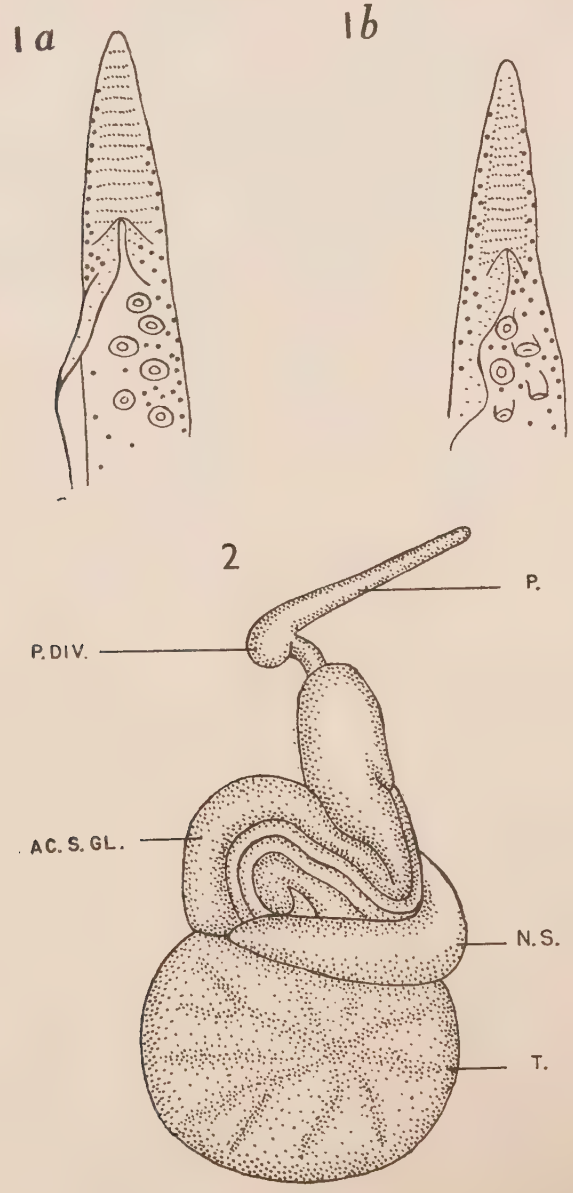


FIGURE 1*a*. Ligula of specimen No. 3.
FIGURE 1*b*. Ligula of Specimen No. 1.
FIGURE 2. Genital system of male specimen No. 1. P., penis; P. DIV., penial diverticulum; AC. S. GL., accessory spermatophore gland; N. S., Needham's sac; T., testis.

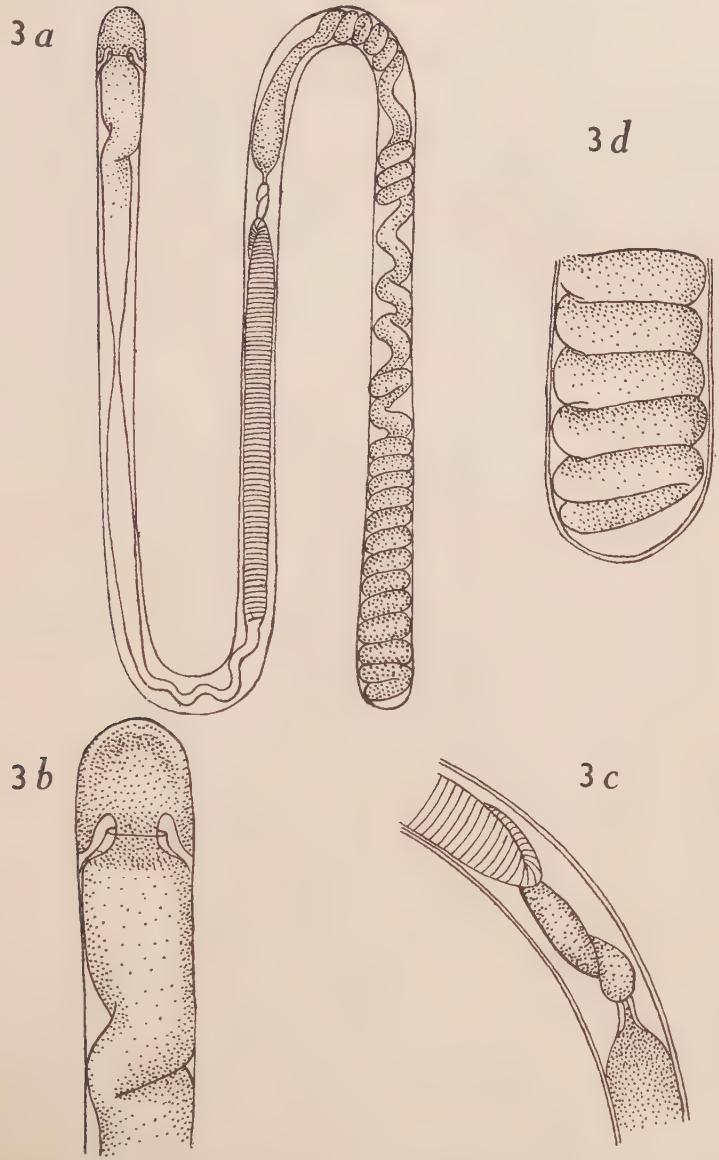


FIGURE 3*a*. Complete spermatophore from specimen No. 1.
FIGURE 3*b*. The head section from the same spermatophore, greatly enlarged to show the details of the cap and the distal coil of the horn.
FIGURE 3*c*. Details of the middle piece showing turn and the adjacent parts of the sperm sac and reservoir.
FIGURE 3*d*. Detail of the end of the sperm reservoir.

organs. These are typical and are shown in Figure 2. As is shown the penis is quite long and slender and *in situ* is invested in the visceral integument for about 80 per cent of its length. In one of the four males it is loosely coiled but this may be due to preservation as in the others it is straight. The penis length index is perhaps misleading as the diverticulum which is included in the measurements is rather small and compact and is actually only a small percentage of the index. The diverticulum in all of the specimens is partially bifurcate posteriorly, forming two incomplete rounded lobes.

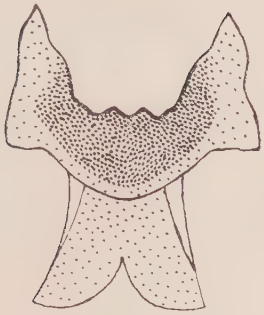
The characteristics of the spermatophores are given in Table IV.

TABLE IV

Octopus burryi Voss. Spermatophore Characteristics of Spermatophores from Specimen No. 1

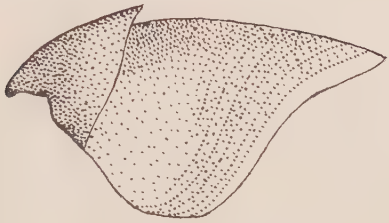
Specimen	Mantle Length (mm.)	Sperm. Length (mm.)	Horn Coils	Sperm. Length Index	Sperm. Reservoir Index	Sac Index
No. 1	39.0	23.6	4	60.5	46.5	25.4

The spermatophores in specimen No. 1 were dissected out and seven spermatophores were studied, there being very little variation detected. A typical, complete spermatophore is given in Figure 3. It is 23.6 mm. in total length, nearly completely transparent at the anterior end, the posterior end with the sperm reservoir being very plainly demarcated. The sperm reservoir (Figure 3*d*) is 11.0 mm. in length and occupies about 46.5 per cent of the total length. At the posterior end it is tightly coiled and the tube heavily pigmented with reddish-brown. At this point the reservoir is 0.3 mm. in diameter. After about the first 10 to 14 coils, the spirals become irregular and partially opened, the total number of spirals averaging about 30 turns although the last two or three coils are difficult to determine. The true appearance of the middle piece (Figure 3*c*) is difficult to ascertain as a certain amount of deterioration has set in so that it is distorted by the pressure of the sperm sac, but one full turn has occurred in all of the specimens examined. The sperm sac is long, averaging about 6.0 mm. and marked by many fine spirals in the wall. The horn makes three clockwise revolutions where it joins the sac and then becomes straight, narrowing to a thread about halfway to the head, after which it expands to its former size. After the initial three revolutions at the sac, the horn is straight until about 0.8 mm. from the head where it performs one full revolution and then straightens out to the end.



4 *a*

4 *b*



4 *c*

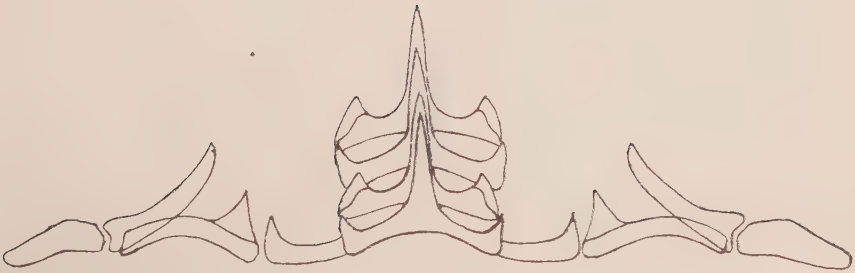


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FIGURE 4*a*. Ventral view of lower mandible.
FIGURE 4*b*. Side view of lower mandible.
FIGURE 4*c*. Side view of upper mandible.
FIGURE 5. The radula.

Eleven spermatphores were found in specimen No. 1 located as follows: one in the primary accessory spermatophoric gland, nine in Needham's sac arranged longitudinally and partially invested by the thin folds of the sac, and one lodged partially in the penis and partially in the penial diverticulum.

Specimen No. 2 was completely dissected out for a detailed examination of the mandibles, radula, and digestive tract. The mandibles (Figure 4) are well devolped and heavily pigmented, the upper rather strongly hooked, the lower one truncated at the tip. The radula (Figure 5) has a simple symmetrical A_2 seriation, the rhachidian teeth being long and slender with wide arched bases. The first lateral is well developed with a single cusp, the second lateral strongly arched, the third lateral long and saber-like. The marginals are large and sharply angled.

The digestive system (Figure 6) is typically octopodan with the exception of a thin-walled intestinal caecum about midway of the intestine. The ink sac is moderately involved in the ventral surface of the liver and the duct joins the rectum at or immediately adjacent to the anus which is furnished with a pair of lateral valves. The funnel is stouter than is usual in the octopods of the western Atlantic and more pointed than usual with a simple large W-shaped funnel organ.

With the addition of the new material it seems likely that *O. burryi* will be found to be endemic to the West Indies and Gulf of Mexico. The holotype was taken, as stated above, from the southeast side of the Florida Keys in 100 fathoms. Specimens Nos. 2, 3 and 5 were taken to the northwestward of Loggerhead Key Light, Dry Tortugas, Florida in depths of from 25 to 30 fathoms. Specimen No. 1 was captured in 38 fathoms about 54 miles SSW of Mobile Bay, Alabama while specimen No. 4 was taken from 14 fathoms about 45 miles west of the town of Campeche, situated on the west coast of the Yucatan peninsula. The localities from which this species has been captured therefore embraces nearly the length and breadth of the Gulf of Mexico. The vertical distribution which is seen to extend from 14 fathoms to over 100 fathoms perhaps explains why this species has escaped notice until the present time. No doubt the extensive fisheries explorations in progress in the Gulf of Mexico at the present writing will materially increase our knowledge of this and other species of cephalopods.

The new material presented here shows that *O. burryi* is a compara-

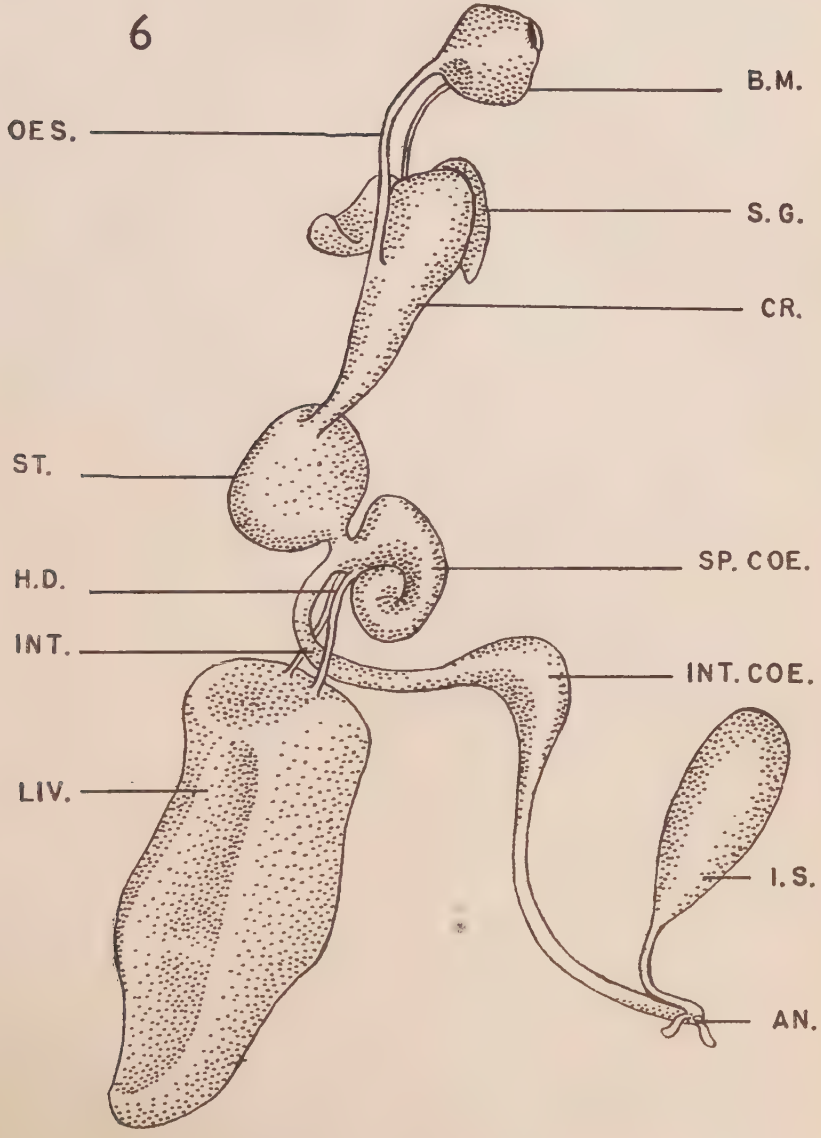

FIGURE 6. Digestive system of specimen No. 2. B. M., buccal mass; OES., oesophagus; S. G., salivary gland; ST., stomach; SP. COE., spiral caecum; H. D., hepatic duct; LIV., liver; INT., intestine; INT. COE., intestinal caecum; I. S., ink sac; AN., anus.

tively small species with rather strongly consistent characteristics in regards to the sculpture of the skin and the purple markings on the arms. The radula is interesting as the marginal plates are well developed and strongly angled, a condition which is apparently unusual in the octopods. The number of lamellae per demibranch of the gills is high as it is with *O. macropus* and *O. vulgaris*. It may be separated from the first, however, by the much shorter arms, coiled spermatophore horn and general body configuration and from the latter by the much higher ligula-length index, and the low number of spermatophore horn coils. The large female was gravid, the ovary containing many small yellow eggs but they were not considered advanced enough to warrant description on the basis of this material. They appeared to be typical, about 1.0 mm. in length, elongately oval with short stalks.

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